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- The Navy's Nuclear-War-Fighting Role
- THE BUTTON: Will It Work?
- Ultimate Weapons:

Star Wars' Chief Scientist, Gerold Yonas

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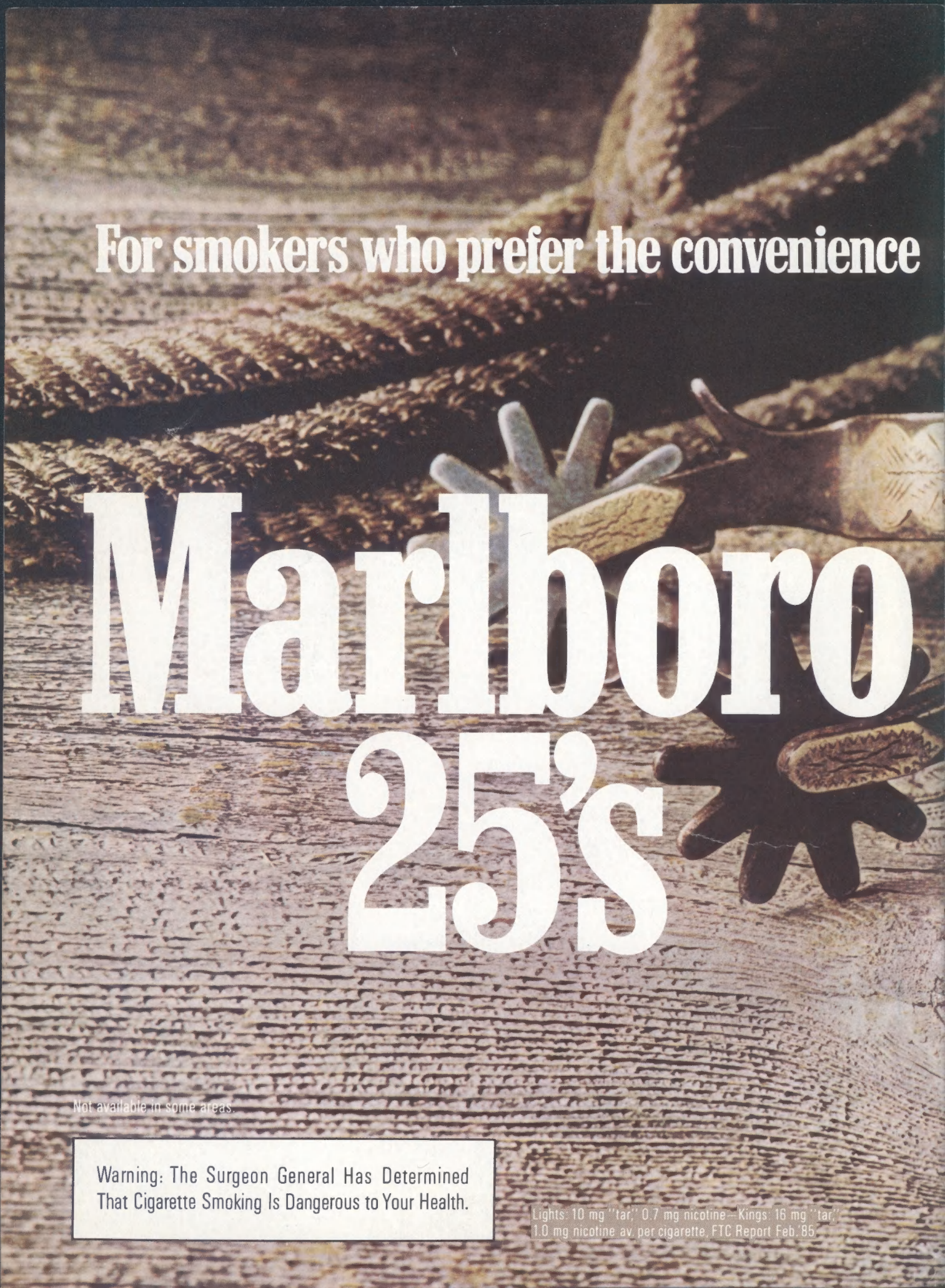
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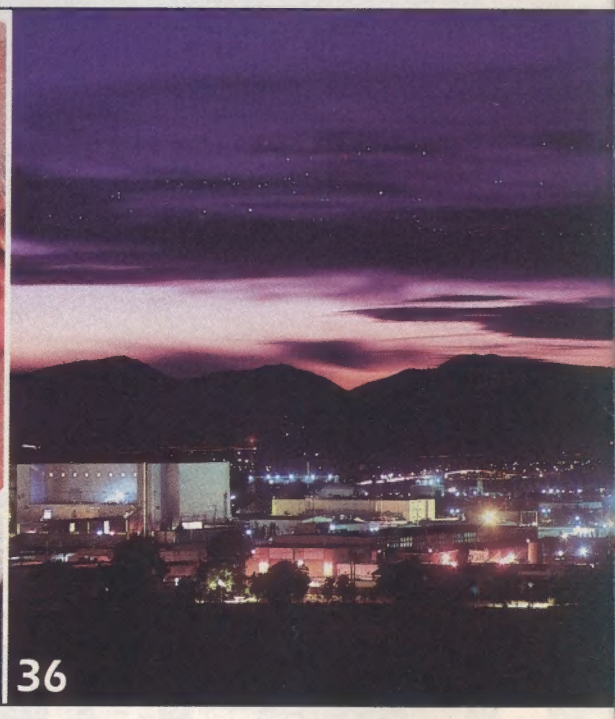

Kinuko Craft drew this portrait of Gerold Yonas, Chief Scientist for the Strategic Defense Initiative Organization. In the background, gladiators jousting in the heavens exemplify Star Wars, and below, the United States is protected by a fortress of missiles.

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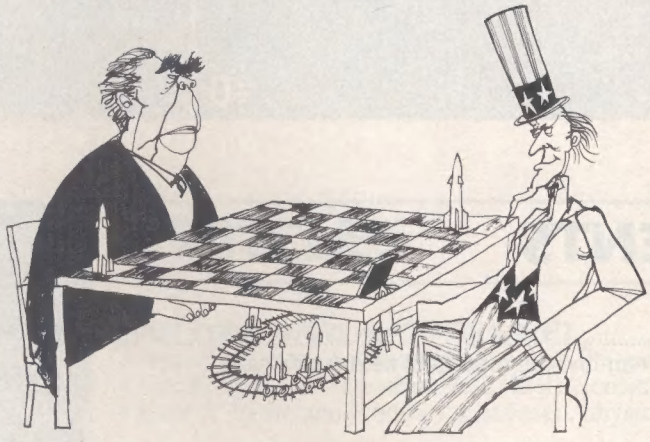
Editor's Note

Thinking About Defense

Ever since the scientists of the Manhattan Project succeeded in translating Einsteinian theory into mega-reality, mankind has wielded the potential for self-destruction. In the early days of the Atomic Age it was some comfort that the trigger finger was American. But no more. Today the Damoclean sword of atomic obliteration hangs evenly balanced above the two superpowers.

The strategic-defense policy of the postwar years goes by the acronym MAD, which stands for mutual assured destruction. Until very recently, it has been an accurate description of the superpower stalemate: point counter point. Ironically, this policy of Armageddon has also produced the greatest period of peace and prosperity of this century. The conflicts of the postwar years pale by comparison with the Thirty Years' War or World Wars I and II.

New technology has continually upped the ante throughout the history of warfare (see "Man's Deadly Quest," page 50). The invention of the stirrup, which allowed a man to focus the weight of horse and rider on the point of a lance, spelled the end of shield-wall infantry. The Gatling gun, which was introduced in the Civil War, was the death knell of massed infantry formations, though it took the carnage of World War I to make the lesson clear to many commanders.



Today, technology is on the verge of revolutionizing warfare again. The forces of change are twofold. The first was the development by the Soviets in the 1970s of missiles accurate enough to strike a Minuteman silo in the continental United States. On the face of it, an innocuous development. Why would the Soviets knock out a silo if the United States retaliated by taking out Leningrad, according to the dictates of mutual assured destruction. A city for a silo? The problem for military planners is that the response is not acceptable to a moral society and, as a result, lacks credibility. We know it and they know it.

Strategic game planning is much like a chess game between grand masters that is resigned many moves before the checkmate. All it takes in strategic-defense matters is to know that the balance of terror has been inalterably changed. The battle itself need never be fought to a bloody conclusion.

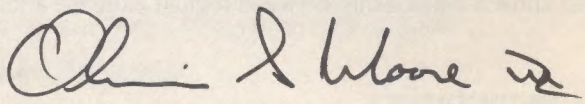
I first became aware of these new developments in 1975 while covering the defense-budget debates in Congress. Secretary of Defense James Schlesinger put forth a new policy of counterforce, which called for the design and development of accurate weapons with silo-busting capability to restore the balance. It was the birth of the MX. In the interim the United States would put its nuclear force on a first-strike footing now known as launch-on-warning. This would effectively prevent a repeat of Pearl Harbor, with our missiles caught on the ground like sitting ducks. Since then, experiments on jamming communications with ionizing radiation indicate that communications during a nuclear attack will be impossible. If a president wants to direct the U.S. counterattack, he must in fact launch first (see "The Button," page 40). It is a chilling and sobering state of affairs.

The second technological innovation that threatens to unravel the Gordian knot of mutual assured destruction is the theoretical work under way on laser and particle weapons capable of intercepting incoming rockets. President Reagan's Strategic Defense Initiative, or Star Wars, as it is known, is public recognition of work that has been going on for at least a decade. I identified R&D money allocated to these weapons during those weeks in Washington back in 1975.

Star Wars is the most ambitious effort to date to end the nuclear stalemate. At present, no scientist can say for sure whether such a complex defense system, operating in space, can work effectively. But some of the brightest minds in the country are betting that it can (see "The Star Warriors of Lawrence Livermore," page 36).

Meantime, the public debate is just beginning. While the answers are not yet known, the questions can certainly be posed. To help clarify the issues, *Science Digest* invited Nobel-prizewinning physicist Hans Bethe, an outspoken critic of SDI, and Dr. Gerold Yonas, the scientist in charge of implementing the Strategic Defense Initiative, to present their views on paper. Their debate begins on page 30.

I urge you to follow the discussion closely in the months ahead. For ultimately you, as an informed citizen, must exercise your judgment on what is surely one of the most important issues in history. Fill out the Strategic Defense Questionnaire on page 82. It will be forwarded to congressional leaders and the White House. We will tabulate the results and publish them in an upcoming issue. ■



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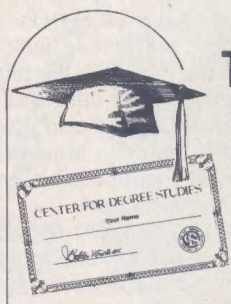

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Contributors

Scrutinizing Our Defenses

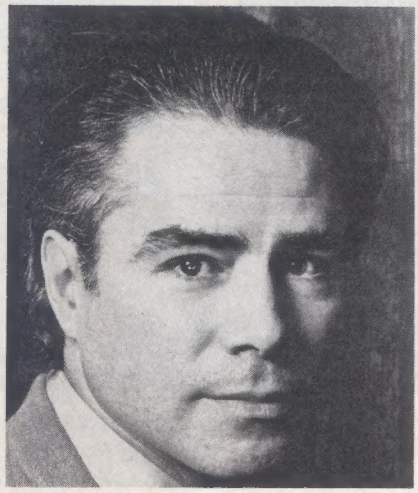
For someone who considers himself a peaceful person, **Tom Gervasi** is fortified with knowledge about weapons. As director of the Center for Military Research and Analysis, he supervises the production of the *Arsenal of Democracy,* a weapons catalog published every three years. The book contains a detailed listing of weapons produced by the United States, describing capability, price, sales and total number in service.

Gervasi, however, is an arms-control advocate. The first edition of his catalog, which appeared in 1978, focused on the arms trade—exposing flawed policies, risky sales and conflicting goals and agreements. It was an immediate best-seller, and Gervasi made national news. Despite its challenges to the Administration's weapons expenditure, "the catalog is used like Roget's *Thesaurus* at the Pentagon," says Gervasi. "But," he adds, "there is a growing readership among the arms-control people."

While Gervasi feels he has become an authority on weapons, he regrets "how much of our finest skill and technology is reflected in weaponry." With the printing of each new volume (the third was published in March), Gervasi also offers a statement about trends in arms policy, new developments and possible consequences for domestic security.

His latest book, *The Myth of Soviet Supremacy,* is due out shortly and "could be very unpleasant for the Reagan Administration." It compares Soviet and American capabilities and numbers and discusses what it means to have "superiority." "I found it really means nothing except in political terms," says Gervasi. "Trying to achieve superiority just gives the Administration license to spend more money on weapons."

On page 50, Gervasi takes us through a historical retrospective of weaponry.



Gervasi: An arms-control advocate, he knows this country's arsenal inside out.

Ford: In the event of a nuclear strike, do we have the capability to retaliate?

Star Wars technology, more formally known as the Strategic Defense Initiative, has been held out as a possible way to end the nuclear arms race. But how does Star Wars work, and who are the brains behind it? That was what **William J. Broad** set out to discover when he visited California's Lawrence Livermore Laboratory. His book *Star Warriors,* due next month, details the week he spent with an unusual group of young scientists who are the heart of the research effort.

"The brightest brains in the country can be found at Lawrence Livermore," comments Broad, a science writer for the *New York Times* who also covers technology and the shuttle, among other topics. "I came back to New York euphoric about the technology." The small group of gifted scientists at the weapons research laboratory, says Broad, work very long and peculiar hours, drink cases of soft drinks and are advancing the cutting edge of technology at a remarkable pace.

Broad found that the group was stimulated by developing the technology that could end the threat of nuclear war. Some of the participants had made significant sacrifices in their personal lives to continue working on the project. Despite his impressions of the scientists and the technology, Broad feels the experience has made him a Star Wars skeptic. He was not convinced that a system could be developed that a countermeasure could not penetrate. His visit has forced him to "think about strategy. The issue goes beyond the technology. The meaning of Star Wars in terms of military strategy and economics must be considered," he stressed.

For an exclusive excerpt from the forthcoming *Star Warriors,* see page 36.

After reading an article on the government's command and control of nuclear forces, **Daniel Ford,** a frequent contributor to *The New Yorker,* was left wondering whether "we have the ability to retaliate at all." How could the President direct the use of nuclear weapons in a crisis? Ford decided to find out—to examine the reality of the so-called button, symbol of presidential control of the country's nuclear weapons. The result: *The Button,* a book published last spring.

"The standard account of presidential control—and the use of nuclear weapons only in retaliation for Soviet attack—turns out to be a piece of contemporary folklore," Daniel Ford states in his prologue. He spent two years researching, interviewing top security advisers and defense officials and visiting key bases such as the NORAD Cheyenne Mountain Complex, which determines whether the Soviet Union has launched an attack, and the Strategic Air Command's Airborne Command Post, which is supposed to ensure centralized control after an attack. Ford's detailed inspection of the military communications system led him to conclude that in a crisis the President might strike first for fear that his communications system would not enable him to direct a retaliatory strike by the time he was certain Soviet rockets were airborne.

Ford, who was executive director of the Union of Concerned Scientists for seven years, created a stir with his book. The military "doesn't like it at all," he says, noting that a number of subjects explored and criticized in the book the Air Force now refuses to comment on.

For an excerpt from *The Button,* see page 40.

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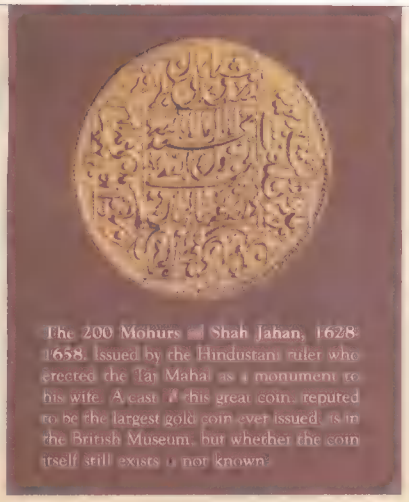

The 200 Mohurs of Shah Jahan, 1628-1658. Issued by the Hindustani ruler who erected the Taj Mahal as a monument to his wife. A cast of this great coin, reputed to be the largest gold coin ever issued, is in the British Museum, but whether the coin itself still exists is not known.

miniatures of the great gold coins of the world. It is an adventure that will provide endless hours of enjoyment for you and your family. And your complete collection will be a significant legacy for future generations to enjoy in turn.

But, remember: subscriptions will be accepted in strict sequence of receipt and once the numbered limit of 25,000 has been reached, the edition will be closed forever. It is therefore important that you return the accompanying subscription application promptly—and, in any event, by September 30, 1985.

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A limited edition of 25,000 complete sets.

Please mail by September 30, 1985.

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☐ YES. I wish to subscribe to *Solid 14 Karat Gold Miniatures of the World's Great Gold Coins*, consisting of fifty finely detailed miniatures, to be sent to me at the rate of one each month, at the price of $35.* each. I will also receive a presentation case, magnifier and collector's tongs, at no additional cost.

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The fifty most significant gold coins from all over the world — as chosen by leading numismatic experts — authentically re-created in finely detailed solid gold miniatures.

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"As rich as Croesus" . . . "the M touch" . . . After more than 2 years, we still speak of Croesus Midas—rulers of the ancient re of Lydia in Asia Minor, a land wh rivers were rich in gold, and wi the world's first gold coins were sued. And through all the centu since, gold coins have been the r precious and universally recogn form of money.

Now, for the first time, you wi able to acquire a collection that bodies all the romance, beauty historical interest of gold c throughout the ages. A collectio fifty miniatures minted in solic karat gold, re-creating — in autl tic and unparalleled detail — great gold coins of the world.

A remarkable achievement— an exciting collection to own

Creating this important collection has been a long and challenging task. Indeed, more than two years have been spent in *locating* all the original coins and arranging to have them represented in this collection. Thus, it will include authentic replicas in miniature of fifty of the greatest gold coins the world has known—from the *Stater of King Croesus* to the *Brasher Doubloon* . . . from the Persian *Daric* of Darius the Great to the *scudo d'oro* of Florence under the Me-

Miniature coin (at bottom right) reproduced 4 times larger than actual size to show fine detail.

dici . . . from the 200 *Mohurs* of Shah Jahan—the largest gold coin ever issued—to the high relief U.S. $20 Gold Piece created by the great American sculptor Augustus St. Gaudens—widely regarded by numismatic experts as the most beautiful gold coin of modern times.

To re-create these great gold coins of the world in miniature was an enormous challenge for The Franklin

to enable you to study each miniature in all its fine detail, a special magnifier and a pair of collector's tongs will be included. In addition, each miniature gold coin in the series will be accompanied by a fascinating commentary written especially for this collection by a noted numismatic expert.

As a subscriber, you will build your collection at the convenient rate of one gold miniature coin per month. And the issue price of $35 will be *guaranteed* to you for each of the solid 14 karat gold miniatures in the collection. To make this important

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An exciting and educational adventure in collecting

There could hardly be a more interesting and worthwhile adventure in collecting than to acquire authentic miniatures of the great gold coins of the world. It is an adventure that will provide endless hours of enjoyment for you and your family. And your complete collection will be a significant legacy for future generations to enjoy in turn.

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Letters

Too Soon for the Scrap Heap?

In his article "It's Pay Off or Perish for the Shuttle" [May 1985], Mike Toner did an excellent job of presenting the hard but true facts about the shuttle's not-so-good record. But with the Russian version of the space shuttle just around the corner, the United States must strive to take the bugs out of STS even if it means a short-term financial loss. Can we afford to fall behind?

Sepehr Behram
Rockville, MD

Mike Toner's article on the shuttle program seems to be well researched. However, I have to take issue with the attempt to show the shuttle, as well as other space endeavors, on the scrap heap.

Tim Ragsdale
Whittier, CA

LITTLE FUTURE FOR THE BIG CATS?

Being a cat fancier, I enjoyed Hope Ryden's article, "The Swift and the Savage" [May 1985]. In particular, the explanation of all cheetahs' genetic similarity was fascinating and new information to me. My compliments as well on the beautiful photography. But Ryden overlooks one unpleasant but plausible conclusion to the information she presents in her article. It sounds as if the combination of man's encroachment and the cheetah's overly specialized evolution has left the cat with no ecological niche to fill. As beautiful as cheetahs are, and as old as their lineage is, they may have outlived their usefulness on this planet. Nature may have different plans for the cheetah than we do.

Anthony Trauring
Decatur, GA

Hope Ryden's article was pleasantly readable, but its lack of depth made it unsuitable for a science magazine. I doubt whether the cheetah's speed, hunting style, choice of prey or number of offspring was news to many readers. On the other hand, more could have been said about other matters, such as the cheetah's genetic uniqueness or its interesting hyoid bone, which determines the cat family's roarers and purrers.

Ryden attributes the reluctance of cheetahs to breed while in close female-male confinement to "brother-sister bonding." While this is a nice, discreet term that accommodates our incest taboo, it is anthropomorphic, mythical and unscientific. Animals in general do not noticeably demonstrate an aversion to mating with siblings or parents. Their reluctance to breed in captivity is almost certainly due to the artificial conditions imposed on them—especially since so little is known about their private lives in the wild.

"The Swift and the Savage" is, however, a commendable pitch for conservation and ecology consciousness.

Stuart Burdick
Mountain View, CA

TRUTH OR FICTION?

I feel compelled to write this letter due to an ongoing controversy among my colleagues.

The story "The Eudaemonic Pie," published in two parts [April and May 1985], is certainly provocative, the concept is rib-tickling, and the writer is very skillful. But, the big question remains, however: Is it pure fiction?

Malvina Salwen
La Jolla, CA

No, it's true. But at present, computers and chaos theory have not broken the bank.–Ed.

SPEAKING UP

I recently read your article on stage fright, "When All Eyes Are on You" [Behavior/digest, May 1985]. I want to thank you for the advice given in the article. As a college student enrolled in a speech class, I am happy to hear I am not the only person who gets frightened and freezes in front of strangers.

Gillian Kassab
Troy, MI

PUMPING IRON PROPERLY

As a faithful weight lifter, I enjoyed the article "Home Fitness Machines" [April 1985] by Tom Yulsman, but felt that you could have included more on such aspects as proper breathing and proper muscle-exertion techniques that help one get the most out of exercise. I also feel that you should be careful of such hasty generalizations as Patrick Netter's statement that "any kind of resistance training will make you stronger and shapelier." Technique is the key to exercise—not the equipment or the type of training.

R. J. Sackett
Menomonee Falls, WI

HIGH COST OF DOING NOTHING

More and more often we seem to be hearing about the high cost of installing scrubbers on smokestacks to reduce the sulfur dioxide emissions ["EPA Tightens Smokestack Rulings," Newscience, May 1985]. The power companies like to warn consumers that these high costs will be passed on to them. Rarely do we hear about the cost of doing nothing—which has become considerable.

Research has shown that acid precipitation is affecting timber yields. A reduction of 10 to 15 percent over the next several decades will ultimately result in higher housing costs. Other studies estimate the cost of structural damage due to acid precipitation to materials such as mortar, metal, textiles, papers and paints at $13 billion a year.

Consumers are already paying dearly, through taxes, to repair damage caused by acid rain. Our government spends more of our tax money on trying to prove whether or not there is a problem than on actually doing something about it. The money could be better spent finding economical solutions or help to pay for these expensive scrubbers.

Karin Henn
Parma, OH

DON'T BLAME THE EPA

It is inaccurate and unfair to blame the EPA if "their" greenhouse effect turns out to be minimal or even reversed. ["Greenhouse Earth Revisited," Followup/digest, April 1985]. The EPA responds to enormous political, economic and philosophical pressures. At the heart of the matter are scientists, publishing outside their field of expertise and in organs that have no strict policy of peer review, who are willing to compromise intellectual honesty to advance a particular point of view and a media that entices them to do so.

The country will continue to go from crisis to crisis, fighting imaginary fires and expending energy and resources uselessly, until scientists themselves restore integrity to their profession.

L. M. Foster
Corvallis, OR

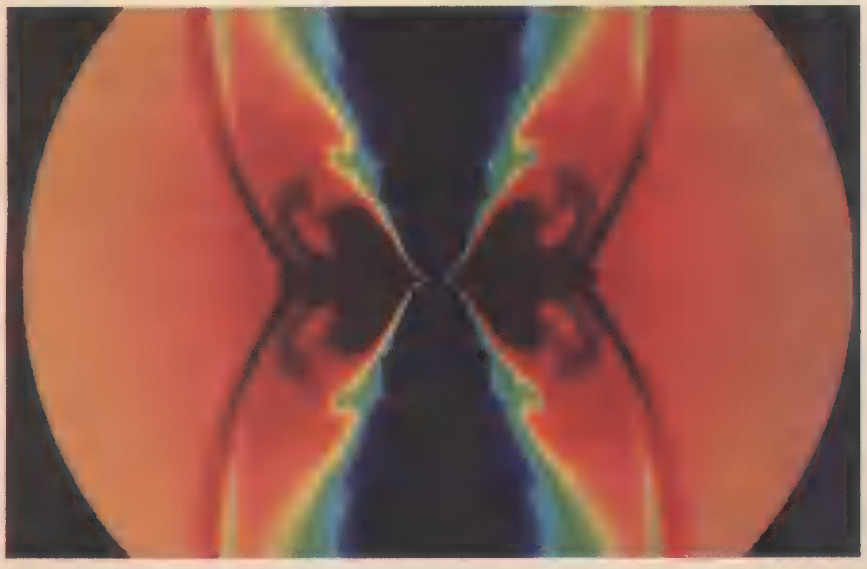
Please send your letters to: Editor, Science Digest, *888 Seventh Ave., New York, NY 10106. Please note we cannot respond to all of the letters we receive each month.*

CHALLENGER SNAPS A DAZZLING AURORA

This dazzling band of light is the aurora australis—the Southern Hemisphere's version of the northern lights—as photographed by astronaut Robert Overmyer, flying on the Spacelab 3 mission aboard the shuttle *Challenger*.

Auroras are caused by charged particles from the solar wind. They spiral to Earth along the lines of force that mark our planet's magnetic field, exciting atoms in the upper atmosphere; this display took place halfway between Australia and Antarctica. The photograph was part of the most extensive auroral study ever made from a manned spacecraft.

The blue-green band and the tall red rays are aurora, while the brownish glow parallel to the horizon is a luminescence of the atmosphere, called airglow. Clouds in the lower atmosphere are illuminated by moonlight.



BLACK HOLE CREATED BY SUPERCOMPUTER

It looks like a piece of abstract art, but this is really a simulation of the flow of gas around and into a spinning black hole. Colors represent the density of the gas as it crowds together under crushing tidal forces: Red regions are densest, blue areas most tenuous. Right at the center is the last stage of the process, gas accreted into a disk before it spirals into the black hole.

Astrophysicists John Hawley, now at Caltech, and Larry Smarr, of the University of Illinois, set up partial differential equations describing the black hole's gravitational field; the solutions were calculated and displayed on a Cray-1 supercomputer at the Max Planck Institute in West Germany.

PHOTOGRAPHS: TOP, COURTESY NASA; BOTTOM, COURTESY J. HAWLEY (CALTECH) AND L. SMARR (U. OF ILLINOIS), PUBLISHED IN SCIENCE, APRIL 26, 1985

NEWSCIENCE

BIOTECHNOLOGY
Glue from the sea

■ The Navy has hired the Genex Corporation to synthesize ■ "super glue" produced by mussels. These unassuming mollusks grip surf-pounded perches by extruding threads covered with a tough, water-resistant adhesive. Isolation and characterization of the protein, the first step toward synthesis, was recently accomplished. The substance could have myriad uses—binding bones, sealing ships' bottoms, saving teeth.

■ A subsidiary of Britain's Imperial Chemical Industries is extracting plastic from certain bacteria. These microbes store energy derived from digested sugars as polyester—just as humans store excess calories as fat. The biodegradable product, called Biopol, may end up in sutures and as a matrix to support regrowth of injured tissue.

COMPUTERS
Have disk, will copy

■ Taking ■ cue from the Pepsi Generation, two innovative Japanese companies have turned to vending machines to peddle software. For the equivalent of $20 in yen, a customer can have one of 60 programs copied onto his own floppy disk. Brother Industries Ltd., the typewriter maker, and Intec hope to install the machines in some 2,000 stores.

■ After William the Conqueror seized England, he took a census of its people and resources—that is, its taxability. The result was the Domesday (pronounced Doomsday) Book of 1086, the best collection of data on the Middle Ages.

Now the BBC has launched its own, computerized Domesday project. Maps, pictures, data and text—all describing the United Kingdom's peoples, society, environment and organizations in the last years of the twentieth century—will be digitized and entered on disks.

ZOOLOGY
The gift of grazing

The value of herding behavior for grazing animals is obvious: The individual is safer from predators when it stays in a crowd.

There is ■ less obvious benefit as well, says Syracuse University's Samuel McNaughton, writing in *American Naturalist.* Grazing is good for the food supply. A grazing herd actually increases the hardiness and thickens the foliage of the grasses and plants it eats.

McNaughton made field observations in the Serengeti Plain of Kenya and Tanzania, measuring the height, mass and growth characteristics of plants. He found that nibbling, like pruning in the garden, causes plants to get bushier. And when all plants are leveled, it's the hardiest among them that live and continue to reproduce.

Mussels cling to objects by producing long "byssal threads" that are coated with ■ special glue. Most man-made glues work only because of mechanical forces. The mussel's adhesive creates chemical bonds with the substrate—even when wet.

Grazing in herds, animals such as these zebras in Kenya are not only protected from predators, they're improving their food supply by promoting short, bushy plant growth—higher in protein and more easily digested than tall growth. And, the animals don't have to work as hard since they get more leaves with each bite.

HALLEY'S COMET WATCH: On the nineteenth of this month, the comet will be 2.5 times as far from the sun as Earth is. It will be visible in large telescopes, between the constellations Gemini and Taurus.

MISCELLANY
Patent patterns

■ Is America's edge in inventiveness slipping? If the number of new patents is meaningful, then the answer is yes. In 1960, only 17 percent of U.S. patents were awarded to citizens of other countries. Of the 72,651 patents issued by the U.S. Patent and Trademark Office in 1984, *42 percent* went to foreign inventors. More than 11,600 were filed by Japanese; West Germans garnered 6,403.

■ *Publications of the Astronomical Society of the Pacific* has disturbing news: Since World War II, the average paper published in physics, math, chemistry and astronomy journals has tripled in length. Reasons put forth by experts range from poor writing skills to a genuine increase in things to say.

PHYSICS
Trapping the atom

Scientists at the National Bureau of Standards (NBS) and the State University of New York, Stony Brook, have trapped an atom and held it still.

Atoms typically move about at roughly 500 meters per second. Scientists would like to slow them down so they can be studied more closely. Charged atoms have been successfully tackled with electromagnetic fields. But neutral atoms, with no charge to provide a handle, were elusive—until now. NBS and Stony Brook scientists recently slowed neutral sodium atoms with a laser beam and locked them in place with an electromagnetic field. These atoms can be held by weak magnetic forces because they act like tiny bar magnets: They are attracted by fields of opposite polarity.

"The human race built most nobly when limitations were greatest and, therefore, when most was required of imagination.... Limitations seem to have always been the best friends of architecture."

–Frank Lloyd Wright

PHOTOGRAPHS: TOP COURTESY DR. HERBERT WAITE/UNIVERSITY OF CONNECTICUT. BOTTOM BY PATTI MURRAY/ANIMALS ANIMALS. DIAGRAM BY BOB CONRAD

PALEONTOLOGY
The first dinosaur?

The partial skeleton of what is thought to be the earliest dinosaur has been excavated in Arizona's Painted Desert.

The newfound fossil, 225 million years old, dates to the Triassic Period, when the continents were still joined and the swampland that became Arizona lay 1,700 miles farther south. According to expedition leader Robert Long, a research associate at the University of California, Berkeley, Museum of Paleontology, the ostrich-size reptile had a long neck and tail and walked chiefly on all fours. It may represent a new taxonomic family related to the plateosaurs, plant-eating dinosaurs that gave rise to the brontosaurs. Long drew his conclusions from a nearly intact hind leg—including claws—as well as from anklebones, thighbones, ribs and vertebrae.

Dinosaurs became dominant in the Jurassic Period, 195 million years ago, and then vanished abruptly at the end of the Cretaceous, 130 million years later.

EDUCATION
Hopkins waives MCAT

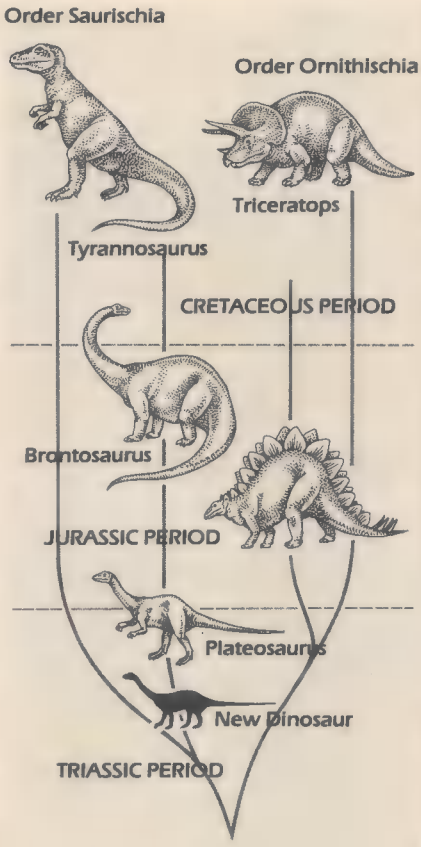
In a dramatic attempt to broaden the typical premed's education, Johns Hopkins University School of Medicine, one of the nation's best, has announced that it will no longer require applicants to take the Medical College Admissions Test. This exam, known as the MCAT, tests proficiency in the basic sciences. In order to do well, would-be doctors often take a plethora of science courses and ignore the humanities. Only one other school, the University of Rochester, has made the MCAT optional.

MEDICINE
The benefits of fish

■ A diet high in saltwater fish lowers risk of heart attack and may mitigate symptoms of arthritis, asthma and hay fever, according to three reports in the *New England Journal of Medicine.* An ounce of fish a day cuts men's risk of heart attack by half. Fish oil lowers triglycerides, thought to play a role in heart attacks. Fish fat blocks the production of leukotriene b4, an immune-system chemical that causes inflammation.

■ A study at the University of Rochester Medical Center links blood transfusions and the recurrence of colon cancer. Pathologist Neil Blumberg and colleagues saw tumors recur in 43 percent of patients who had had transfusions during surgery but in only 9 percent of those who hadn't. Transfusions are known to decrease immune response.

■ While ridding the body of bacteria and carcinogens, certain white blood cells can produce enough toxic substances to turn healthy cells cancerous. Researchers at Harvard Medical School and Mass General injected 43 mice with human neutrophils sensitized to produce toxic oxygen metabolites. Five developed malignant tumors, and six, benign.



Dinosaurs can be divided into two groups. Saurischian, or lizard-hipped, dinosaurs had pelvic girdles with three prongs to a side; ornithischian, or bird-hipped, ones had four-pronged pelvises. The new fossil, the oldest known dinosaur, is saurischian.

"AND WE CAN FILL THE REMAINING SILOS WITH NON-CLASSIFIED INFORMATION, MEMBERS OF SCIENTIFIC SOCIETIES AND PRESS PEOPLE"
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ADMINISTRATION CENSORSHIP PLANNERS
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CHART BY PATRICIA WYNN. CARTOON © 1985 BY HERBLOCK IN THE WASHINGTON POST

BIOCHEMISTRY
Catch-22 for plants

As a defense against air-pollution damage, many plants and animals release glutathione to absorb harmful oxidative chemicals. But glutathione produced by crops attracts insects—and may even fortify them against pesticides, according to findings at Cornell's Boyce Thompson Institute for Plant Research.

Oxidative chemicals, such as sulfur dioxide and ozone, have either one extra electron or one too few. To correct the imbalance, they shed electrons on or rob them from nearby molecules, a reaction that harms healthy cells. Entomologist Patrick Hughes found that Mexican bean beetles prefer soybean plants exposed to these pollutants: The pests chew more leaves, grow larger, lay more eggs and show, perhaps, increased resistance to pesticides.

POLICY
Conference—censored

What if someone gave a scientific conference and nobody could confer?

That isn't a completely fanciful scenario if an imbroglio surrounding a recent meeting of the Society of Photo-Optical Instrumentation Engineers is any indication.

Two weeks before the meeting, the Department of Defense, which sponsored much of the research that was to be described, announced that 43 of the 219 papers could not be presented in open sessions. Thirteen papers contained classified information, DOD said, and the rest were deemed subject to "export controls," because the subject matter—in most cases, lasers—had military applications. A hastily created special closed session saved the event.

NEWSCIENCE

ASTRONOMY
Martian dust devils

■ Mars' thin atmosphere is still dynamic enough to serve as a planet-size laboratory. The latest find is dust devils—dust-laden tornadoes up to three miles high. Cornell researchers Peter Thomas and Peter Gierasch discovered the whirlwinds from the shadows they cast on the Martian surface in orbital photos; 99 have been identified so far.

■ A paper appearing in the May 17 issue of *Science* asserts that the rocky inner planets—Mercury, Venus, Earth and Mars—formed from a cloud of some 500 protoplanets, each the size of the moon. Author George Wetherill, of the Carnegie Institution of Washington, says they collided and consolidated repeatedly, leaving just four in the end.

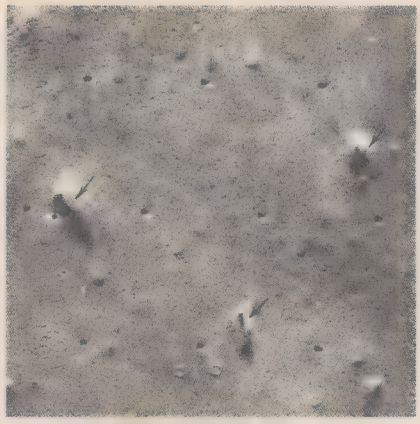
SPACE
Space station update

■ NASA's space station is fast becoming an international project. Canada agreed last spring to spend $8.8 million to study methods for constructing and servicing the orbiting facility and a solar-powered generator for a space platform. Most recently, the Japanese agreed to work on plans for a laboratory module and outside work deck that would be attached to the station; they will spend $22 million over the next two years. The European Space Agency is also expected to participate.

■ In developing the space station, designers will have to consider impacts from tiny pieces of man-made junk. A recent analysis of a pit the size of a sesame seed in a window of the space shuttle *Challenger* revealed that it had been caused by a collision with a particle of paint eight-thousandths of an inch in diameter. The wayward paint chip struck at two to four miles per second.

EARTH SCIENCE
Cloud mystery grows

After sighting a huge mushroom cloud off the Japanese coast last year, an airline pilot issued a Mayday. But it wasn't a nuclear blast; no radiation was detected. Now another suspected source, an undersea eruption, has been cleared. Although volcanic activity was noted near Iwo Jima, Daniel Walker, at the University of Hawaii, reports that winds would have blown a volcanic plume *away* from the mystery area.



While orbiting Mars in 1976, the Viking spacecraft photographed swirling columns of dust up to three miles high (arrows).

TECHNOLOGY
Diving made easier

Phil Nuytten, a Canadian diver and inventor, has designed a deep-diving suit that is a fifth the weight of the half-ton, stiff-jointed type now available. It has an internal oxygen supply and is so flexible, he says, that divers can swim, even "scratch their backs."

Before the Newtsuit, deep diving presented unpleasant options: A diver could don a clumsy armored outfit that counteracted the force of tons of water with brute strength. Or he could wear a flexible suit filled with pressurized air. However, a diver had to decompress for up to a week to prevent gas bubbles from forming in his blood. The Newtsuit offers the best of both options.

TECHNOLOGY
Harnessing g forces

Inventor Jack Gilbert plans to pilot an 18-foot boat up the Hudson River next year at a brisk 25 knots—without paddle, propeller or sail. It will be powered by an internal "g-force propulsion" system that Gilbert says requires just 15 horsepower; a propeller drive would need 65 hp to hit that speed.

The system exploits the same force a gymnast uses to fly off the high bar. A motor spins two horizontal, circular platters in opposite directions. A free-swinging weight is attached to each platter, but off-center. This way, as the platters rotate, the weights are flung outward and then swing in, near the platters' centers. Because the platters have opposing spins, the forces exerted by the weights are canceled—except in one direction. Forward.

BEHAVIOR
Sealed with a kiss

Everything has its purpose, and kissing, it seems, is no exception. Bubba Nicholson, a graduate student at Georgia Tech, reports in the *British Journal of Dermatology* that kissing may chemically bond individuals through the ingestion of each other's sebum, a putative pheromone secreted by the sebaceous glands in the skin.

Nicholson cites evidence that sebum excretion levels are highest during periods when bonding is important: in early adulthood, when courtship behavior is strong, and after birth in both the newborn and the mother.

ARCHEOLOGY
Saving the Sphinx

The Great Sphinx of Giza could lose its head if the erosive effects of 4,500 years of blowing sand are neglected. To support the head, whose center of gravity is shifting forward, the Egyptians want to rebuild the Sphinx's beard and attach it with steel bars. The only drawback is that a crucial, three-foot fragment belongs to the British Museum, which isn't eager to relinquish it.

Although the fragment has lain in the basement for over 100 years, the museum will consent only to *lend* it to Egypt—for a maximum of 99 years. Officials say that giving it back would set a bad precedent in light of Greece's ongoing demand for the Elgin Marbles.

PHOTOGRAPHS: TOP, COURTESY NASA; BOTTOM, BY PAUL LITTLE

VALLEY WATCH
By Ian Anderson

Map reading in a car is no picnic. But if Nolan Bushnell, the founder of Atari, has his way, all that will be changed. The reason: The first practical vehicle navigation system in America. The product is a first for ETAK Inc., a company backed by Bushnell.

I drove to ETAK, in Sunnyvale, California, using the old technology. A folded map was clutched in my right hand as I cruised Lawrence Expressway, but I still went wrong. I should have taken a hard left on Elko to Lawrence Station Road, but I went sailing on past Variquip, Microlog, Syn-Optics, IDEC, Polymetrics and assorted other companies.

Instead of crumpled paper maps, the ETAK Navigator has a CRT display that's mounted under the dash or on a movable arm. On the screen, the position of the car is represented by a small fixed triangle. As the vehicle moves, maps showing its precise location scroll by.

I tried it out the other day. A menu appears when the system is booted so that you can program your destination, and a zoom function lets you depict either the immediate vicinity or a large-scale area. As you turn corners, the map turns too. Sensors on the wheel rims can tell the position of the car by measuring the distance it has traveled. A computer, in the trunk, correlates the data with information it already contains about the map chosen by the driver. The data are updated every second.

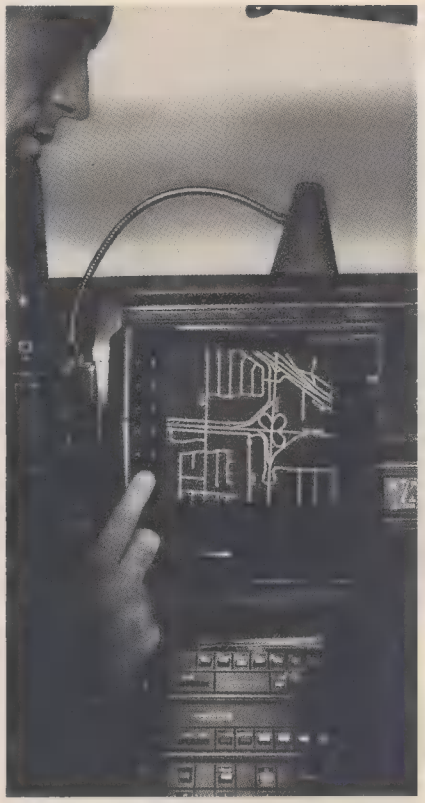
Rush to Buy

The Navigator, equipped with maps of the San Francisco and Los Angeles areas, will be available for either $1,395 or $1,595, depending on screen size. Cassette maps will cost $35 each. Four million dollars' worth of advance orders—about 2,500—have been received.

■ Nabbing suspects fleeing from the scene of a crime should be easier after another piece of equipment is installed in patrol cars.

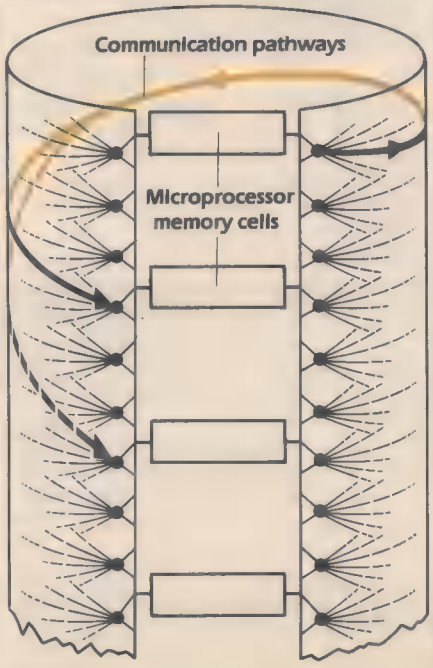
Radionics, in Salinas, has a security system that allows video signals to be converted to digitized audio signals so that they can be transmitted over telephone lines or radio frequencies to a display screen. The system costs $1,500 to $2,000 for the transmission unit and $4,000 for the receiving unit. At the receiving end, a hard copy is printed out. A patrol car could receive by radio an instant picture of a suspect photographed by a surveillance camera. The system could also be used for stakeouts.

PHOTOGRAPH FROM ETAK INC., DIAGRAM BY WALKEN GRAPHICS



A computerized map that rotates with each turn of the wheel can help security guards patrol crime-ridden neighborhoods.

The Butterfly machine solves a traffic problem inherent in parallel-processing computers. Its switching system, shown schematically below, lets every memory-microprocessor module talk to the others.



HIGH-TECH HIGHWAY
By Laurel Lucas

The vanguard of a whole new generation of computers continues to hatch out of that high-tech incubator, the Route 128 area, near Boston.

Traditionally, computers have processed instructions serially, or one after the other. This creates a bottleneck, since each operation has to wait until the previous one is finished.

One approach to creating faster, more powerful computers, therefore, has been to link central-processing units together. The goal is parallel- or multiprocessing, in which several instructions are carried out simultaneously.

The trick in parallel processing has been to overcome diminishing returns. In cooperating on a given problem, each processor must share information with all the others. But as more processors are added, communication becomes increasingly complex.

Cheaper Speed

BBN Laboratories and Encore Computer Co. are using an inexpensive strategy to overcome the problem. BBN's Butterfly system uses 256 interconnected central-processing chips—the same Motorola 68000 microprocessors that are used in the Apple Macintosh—to achieve a speed rivaled only by the most powerful supercomputers.

A similar approach has been taken by the Intel Corporation and Caltech; their machine, called the Cosmic Cube, is built around a system of up to 128 of the same Intel chips that run the IBM PC. (*Science Digest*, July 1985, page 62.)

"The fastest computers in use today employ exotic, expensive technologies that prevent them from taking advantage of the cost-performance benefits of today's microcomputer chips," says David Walden, president of BBN. "We've applied the powerful but inexpensive microprocessors to supercomputer tasks."

BBN's strategy is to use a switching network that acts like a super-mailman, allowing each microprocessor speedy access to the local memory chips attached to the other 255 processors. There is also a coprocessor that routes instructions and chooses between local and external memory.

While the Butterfly system's development was funded by the Defense Advanced Research Projects Agency and was intended for research use, the two-year-old Encore Computer Co. is developing a similar system, called the Multimax line, for commercial use.

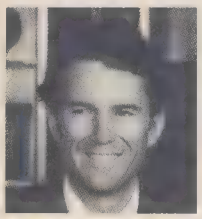
PTEROSAUR TO SOAR AGAIN

Paul MacCready, designer of the human-powered Gossamer Albatross, is now building a computerized model of a pterosaur, a flying reptile that died out 64 million years ago.

Paul MacCready, the master of human-powered flight, has teamed up with University of Texas paleontologist Wann Langston, Jr., to create a robot replica of a pterosaur, an extinct reptile that was the largest animal ever to fly.

Gliding models have already been tested. The full-scale version, which is slated to take flight in November, will have a carbon-fiber skeleton that stretches 36 feet from wingtip to wingtip. The latex-covered wings will flap, pivot and twist, controlled by an on-board computer and a radio link to the ground. Corporate donations and the Smithsonian's National Air and Space Museum are footing the $400,000 bill.

KAYPRO CLAIMS TIDE HAS TURNED



Kay: free advice for reporters.

David Kay, president of Kaypro Corporation, was on the East Coast for a late spring wedding (headquarters are in Solana Beach, California); he stopped in New York City to see some friends and reporters.

Kaypro appeared to be in trouble a year or so ago, losing momentum in the market it had built with its sturdy, functional computers. Now, says Kay, the tide has turned. He seems to be right. The company has issued a flurry of new products, including a full-function lap-top portable and the first IBM-PC-AT-compatible announced. As is usual for Kaypro, prices are lower than average.

"That's all the new-product offerings for a while—at least until sometime in 1986," says Kay. He also suggested a story idea for tapped-out editors: "The Obsolescence of the Typewriter."

WATT STALKS POISONED POT

Entering a new field: biotech.

James Watt, the controversial former Secretary of the Interior, is now chairman of Environmental Diagnostics Inc., a young biotechnology company in Irvine, California. EDI develops inexpensive, easy-to-use kits for the rapid detection and monitoring of toxic or hazardous substances in food, water, livestock and chemical solutions, but its first product—a test to detect paraquat contamination in marijuana—may have caused the straitlaced executive some concern.

Watt emphasizes that the test was never intended for marijuana users, but was developed to prove the effectiveness of EDI's biotechnology. Paraquat, which can be deadly, is one of the most difficult herbicides to trace.

Watt's contacts have also helped to boost EDI's sales. The Department of Agriculture now buys five of its antibiotic-residue tests. And the firm recently received a grant from the National Institute on Drug Abuse to develop a screening test for marijuana use.

BERKELEY'S AMES WINS TYLER PRIZE

His test reliably detects mutagens.

Biochemist Bruce Ames, of the University of California, Berkeley, is one of two recipients of the 1985 Tyler Prize—an international award for environmental achievement—for his development of a quick, inexpensive system that detects potential carcinogens. The Ames test, which became available in the early 1970s, is used by laboratories and chemical companies worldwide to test the DNA-altering ability of thousands of chemicals. Recently, it has been used to discover mutagens that occur naturally in food, tying into Ames's current research on the possible link between cancer and diet.

COUSINS: DEALING WITH HYPOCHONDRIA

He speaks out about how we view pain.

Norman Cousins, the author of *Anatomy of an Illness* and a professor at UCLA's School of Medicine, speaking at Sinai Hospital of Detroit, had some comments on the perception of pain in America.

"It seems apparent that the American people are illiterate about pain. We tend to think that we're immortal until we get a cold, when we think we're going to die within the hour. We have no educational or emotional background for comprehending pain or coping with it. We have been taught to reach for a pill to get rid of the pain. We haven't been taught to make the connection between pain and things in our life-style that may be causing it. So long as our education pushes us in this direction, it's inevitable that we're going to have to deal with hypochondria on an increasingly large scale."

Editors: Andrea Dorfman, Josh Eppinger, Michael Lemonick. Designers: David A. Bayer, Judy Goldstein. Contributors: Pierce Fredericks, Susan Gilbert, Amy Mereson, Andrew C. Revkin, Amy Wilbur, Tom Yulsman.

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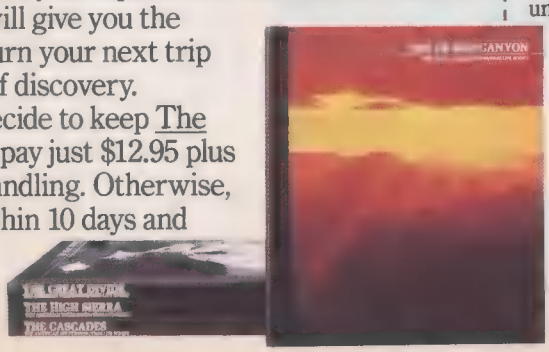

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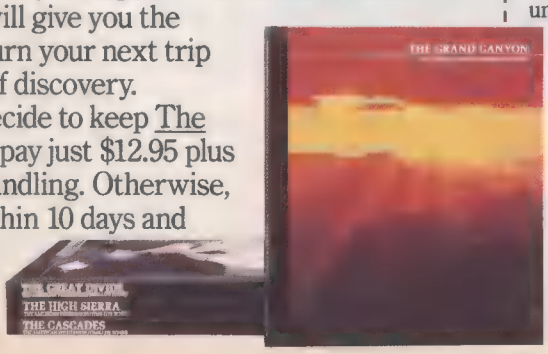

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MAGNEQUENCH Emerges

A new magnetic alloy will revolutionize electric motors.

Physicists, chemists and metallurgists at General Motors Research Laboratories in Warren, Michigan, have discovered a new metal that could revolutionize industry. Called MAGNEQUENCH, it is an alloy of iron, boron and neodymium that retains magnetism better than any other metal. It can be made into the most compact, powerful, permanent magnets in existence.

The implications are enormous for any machine that incorporates an electric motor, from appliances to automobiles, because magnets, mounted on drive shafts and spinning in an electric field, are the central component of most electric motors. And a magnet that's smaller, lighter and cheaper to make will confer the same beneficial properties on any motor-driven product.

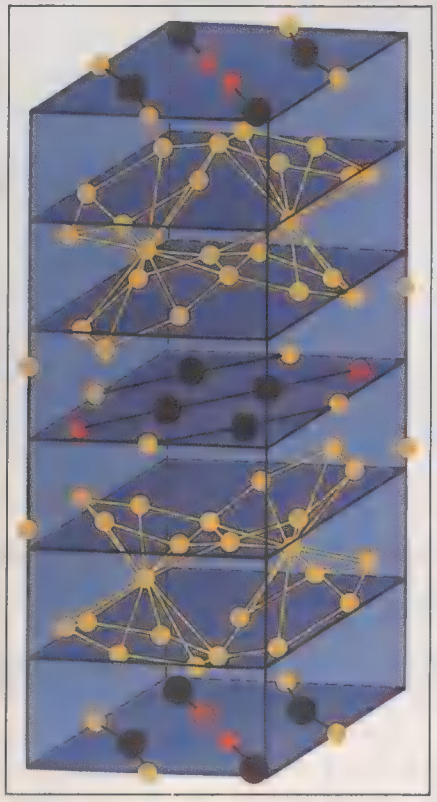
"We think we can cut the weight of motors in half," says William Miller, research engineer and program manager for MAGNEQUENCH. "We've already had inquiries from major appliance and motor manufacturers." GM plans to use it in the starter of one of its 1986 models.

MAGNEQUENCH's remarkable ability to retain magnetism—its magnetic hardness, or high coercivity, to use the proper term—results from its crystalline microstructure, but scientists didn't know in advance what that structure would be. "In metallurgy, you often work by trial and error," says Miller. "We knew that iron can be magnetized, and that neodymium has relatively high coercivity. When we mixed the two, the results weren't all that good. But when we added boron, the crystal lattice fell into place."

Lining Up the Lattice

GM sent the new metal to William Yelon, at the University of Missouri Research Reactor. He did neutron diffraction studies, observing the way neutrons were scattered by the crystals, and that showed how the atoms—14 of iron to 2 of neodymium to one of boron—are arranged.

Magnetism always results from the movement of charged particles. On a macroscopic scale, electrons moving through a wire create an electromagnet. On the atomic scale, electrons orbiting the nucleus of an atom make the atom itself into a tiny magnet (but only in some elements; nonmagnetic atoms have even numbers of electrons spinning in opposite directions; they cancel each other out).



Repeating cells that contain 56 iron (yellow), 8 neodymium (black) and 4 boron atoms (red) make up MAGNEQUENCH.

The granules below are MAGNEQUENCH crystals seen under an electron microscope.

A substance made of such atoms can be permanently magnetized if an external magnetic field can make the atoms line up so that their fields are pointing in the same direction. Their fields combine, and the entire mass becomes a magnet.

Iron is such an element, but it's not very good for making truly permanent magnets. That's because iron atoms arrange themselves in a cubic lattice, with each atom pointing along one of the cube's mutually perpendicular edges. The atoms can be made to point in the same direction, but a shock to the metal—heating or a physical blow—tends to demagnetize it. Each atom need only swing 90 degrees to find another allowed direction.

Keeping Iron in Line

"In a MAGNEQUENCH crystal, on the other hand," says Yelon, "the neodymium and iron atoms, because of their placement in relation to one another, have only two possible orientations: straight up or straight down. It's a lot harder to get an atom to swing one hundred eighty than ninety degrees. And since the magnetic fields of the neodymium and iron atoms interact with and reinforce each other, the iron atoms can't swing away either. If one tries, the rest force it back into line."

The individual crystals in a block of MAGNEQUENCH are only a 10-millionth of an inch across, oriented at random with respect to one another. Their magnetic fields would ordinarily tend to cancel each other. According to Jan Herbst, leader of GM's solid-state physics group, there are two ways to get around the problem. You can melt the alloy at about 1,400 degrees Celsius, then deposit it on a spinning disk, where it cools in a fraction of a second. This process yields small ribbons of metal that are then mechanically compacted, which aligns their crystals. The other solution is to powder the alloy at room temperature, align the crystals with a large magnetic field, then heat them so that they fuse.

Neodymium in Abundance

"Perhaps the best thing about MAGNEQUENCH," says Miller, "is that it's made from abundant, inexpensive raw materials—neodymium is in the class of elements called rare earth metals, but it's actually not rare at all."

Motors aside, the new magnets will have other uses, says Miller. "They'll have applications in hi-fi speakers and nuclear-magnetic-resonance machines in medicine. This is probably the most significant and certainly the most exciting project I've been involved with." ■

–Michael D. Lemonick

ILLUSTRATION COURTESY GENERAL MOTORS CORPORATION; PHOTOGRAPH COURTESY JAN F. HERBST/GENERAL MOTORS RESEARCH LABORATORIES

An advanced computer system for air traffic control is being designed to serve the U.S. into the 21st century. The new Advanced Automated System (AAS) will consolidate existing en route facilities and approximately 130 terminal facilities into 23 area control facilities throughout the country. It will automate many routine air traffic control activities now done manually. Computers will monitor and evaluate air traffic situations and offer solutions to potential conflicts between airplanes in flight. AAS will include controller consoles to display radar data, weather information, and flight plan data; powerful modern computers; and new software to run the new system. Hughes Aircraft Company is designing AAS for the Federal Aviation Administration under a competitive contract. Hughes has built air defense systems for more than 20 nations, including the U.S., Canada, and NATO countries.

Controller-thrust aircraft engines will be tested at NASA's Lewis Research Center with three heat monitors. Three Probeye™ thermal video systems will monitor, measure, and analyze heat from the engines while they are operated within the environmental test chamber at the research center. Each Probeye system consists of an infrared imager, image processor, and TV display, all of which interface with a computer. Hughes designed and produces the Probeye system.

Pilots of future aircraft may rely on artificial intelligence systems to help them assess combat situations and take appropriate offensive or defensive actions. Hughes engineers are conducting studies for the U.S. Air Force on potential uses of artificial intelligence for fire control and battle management. One focus is how to identify targets automatically and present this information for a pilot's use. Another aspect involves tactical analysis, including decision-making that advises a pilot whether to attack, flee, apply electronic countermeasures, or fly low-altitude routes. New automation techniques may be necessary for pilots to cope with the fire control systems now being designed for the next generation of military aircraft.

Interactive computer graphics and advanced laser technology will combine to slash production costs of printed circuit boards. Hughes is developing a computer system called IMAGE (Integrated Manufacturing Artwork Generation Environment) to prepare artwork and numerical-control machine programs for circuit boards. IMAGE receives a computerized description of a circuit board from engineering. Many circuit boards are then laid up electronically on large workboards. The resulting data base drives a laser imaging system, which produces precise artwork. It also produces the programs that tell machines how to drill and rout circuit boards. The system will do in hours what used to take two weeks or more.

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Chaotic Body Rhythms

A biologist uses topology to link unrelated phenomena.

Purdue biologist Arthur Winfree believes an underlying mathematical model that describes two seemingly unrelated phenomena—the internal biological clock, which determines sleep-wake cycles, and an obscure chemical process called the Belousov-Zhabotinsky reaction—also describes a third: fibrillation, the uncontrolled, erratic fluttering of the heart that is a major cause of sudden cardiac death.

If he is right, fibrillation can result from such relatively mild, usually harmless stimuli as the premature firing of a few nerves. Should it happen at just the wrong moment of the heartbeat cycle, it triggers a rotating, three-dimensional wave of electric potential that moves through coronary tissue.

This self-sustaining wave irrevocably overrides the heart's normal, rhythmic beating; even someone with a healthy heart is susceptible. In fact, this could explain sudden heart failure in disease-free people.

Winfree is careful to emphasize that his ideas are so far unproven; yet they earned him a grant from the MacArthur Foundation last November. He is currently on leave from Purdue, working at the University of California, San Diego, and at the La Jolla Veterans Administration Hospital. "I'm trying," he explains, "to learn some cardiology."

The theory Winfree is pursuing rests on a branch of mathematics known as topology, the study of the properties of geometric shapes—and, by analogy, of systems that can be represented by geometric shapes. "My original work on the problem had to do with biological clocks," he says.

Biologists had long believed that over the long term an organism would alternate sleeping and waking at regular intervals. A disturbing stimulus, such as a change in the pattern of light and darkness, might advance or retard the cycle without changing its fundamental rhythm. In fact, this is just what happened in experiments.

"I thought that might not be the whole story, though," recalls Winfree. "The cycle is governed by the interaction of many chemical compounds at many locations in the body. With topology, you can treat all those concentrations as a space of many dimensions, called a phase space. You needn't define its structure in detail to examine its properties."

Winfree treated the sleep-wake cycle as a one-dimensional slice of this many-dimensional phase space. He then described a two-dimensional slice, analogous in structure to a soap film stretched on a circular metal wire. He defined the wire as the ordinary rhythm—movement around the circle represents passage through the cycle over time. The soap film is a set of possible disruptions.

Rotating waves can represent chaotic activity in biochemical systems. The one shown above is a simulation, done on a Cray-1 supercomputer.

In the case of a disruption, represented by a point on the film, the normal rhythm resumes from some predictable spot along the metal rim, just as a point on a soap film rushes to a particular spot on the rim when the film breaks.

"Nearly every spot on the film can be assigned a corresponding point on the rim," says Winfree. "But according to the topological theorem of nonretraction, this can be true only if there is at least one point on the surface that does *not* have such a correspondence. A soap bubble cannot retract onto the rim unless you break it at some point." By analogy, Winfree predicted, there should be a point in the sleep-wake cycle where an applied stimulus would not restart the cycle but would result in an arrhythmic pattern.

"Eric Peterson, a graduate student in biology, tried it on mosquitoes," he says, "and found we could produce a state in which the insects slept, then woke and buzzed around for a while, then dropped off again, in no discernible pattern."

Winfree wondered whether it might be possible to treat other rhythmic biochemical systems the same way. "Since the mathematical model is abstract," explains Winfree, "there seemed to be no reason it couldn't apply to such things as rhythmic chemical reactions, the cycle of cell reproduction, the menstrual cycle or even fibrillation."

The jury is still out on menstruation; the analogy just doesn't work when it comes to cell reproduction. In the Belousov-Zhabotinsky reaction, though, a triggering beam of ultraviolet light interrupts the orderly interaction of a mixture of chemicals, sending a rotating wave front of activity through them.

"We can't say for sure, but the evidence is very good that the same sort of thing goes on in the heart," Winfree concludes. "The contraction of millions of heart cells, based on combinations of electrical and chemical stimuli, make up the phase space. And a mild stimulus occurring at the proper time should disrupt the pattern entirely."

Does the mathematical model have a basis in reality? Two pieces of evidence suggest it does. The first is that electrodes placed on the surface of laboratory animals' hearts have detected what appear to be the rotating spiral waves of electricity that Winfree predicts.

The second comes from the work of George Ralph Mines, a physiologist who did heart research at the University of Montreal in the early years of this century. Mines suspected that fibrillation could be caused by mild stimuli to the heart, though he had no theory to explain it. He may have been proved right. One day, in 1917, he was found alone in his lab, dying of heart failure. Attached to his chest were the wires of a machine he had been using to deliver weak shocks to lab animals. ■

–Michael D. Lemonick

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chemical compounds at many locations in | would result in an arrhythmic pattern. | –*Michael D. Lemonick*

The Pursuit of Money

Psychologists probe the pitfalls of overachieving and making it.

Although few would deny that it's better to be rich than poor, for some people the quest for money is so all-consuming that it extinguishes all other aspects of life, according to psychologists who specialize in treating people of great wealth and power. Scientific studies of the problems that stem from an obsession with wealth are conspicuously absent from psychological journals. However, by reviewing individual case histories, clinicians see certain patterns emerge.

For some people, financial success is a no-win situation. They are driven to make money by a need for approval. But the greater their wealth and power, the less their colleagues think they need approval.

The cause of the compulsion to make enormous sums of money varies with the individual, but often money is a substitute for something a person's life lacks. Says Jay Rohrlich, a psychiatrist in New York's Wall Street district whose clients are mostly executives in the financial field, "To some, money means security. To some it means power. To others it means they're going to be able to buy love, and to a fourth group it means competition and winning the game." The belief that money can produce these things, psychologists say, often leads to impotence, insomnia, heart attacks and problems with a spouse or children.

The Bottom Line

A tremendous need for power is invariably the bottom line for those driven to make a lot of money. "The bigger the pile, the more powerful they *think* they'll feel," says Bonnie Jacobson, a clinical psychologist in Manhattan, who presented a paper in August on the dynamics of power at the American Psychological Association's meeting in Los Angeles. Most of her clients are men in their fifties who work at the executive level of various businesses and take home salaries "with six and seven figures," she says. "Yet in therapy, these people often have an enormously unrealistic feeling of powerlessness."

Parents and family background also influence a person's pursuit of money. Many people who grew up poor and then made a fortune live in fear that they will lose it. Others strive for money to compete with their wealthy, successful parents. "These people are driven to do what their parents did," Jacobson says. "They want to be successful at any price." Oddly enough, she adds, "they don't feel they should enjoy what they have earned."

Rohrlich speaks of clients who see their identity completely in terms of their money and, therefore, are loath to part with it. He describes a man worth several million dollars who lives in a studio apartment, listens to a portable radio and wears 10-year-old suits. All his money goes into his stock portfolio.

Making money for its own sake can be addicting, says Jacqueline Horner Plumez, a psychologist in Larchmont, New York, "like high-stakes gambling." Jacobson adds, "Some very wealthy people work so many hours, so hard and at such an intense pace that they totally neglect themselves. They don't eat right. They don't sleep right. They just work." She describes well-to-do clients who "act as if they're impoverished, as if they're struggling to make a dime." Rohrlich recalls a man who told him he works to make money as if he were "hungry" and that being paid makes him "feel full."

Rohrlich also points out that many wealthy people are driven by the need for approval. "But as you make more money and achieve greater power, others view you as less needy and themselves as needing more from you," he says. This "paradox of power," as he calls it, can lead to feelings of isolation and anxiety. There is no one to pat you on the back and assure you that you're doing a good job. Such a person may go out of his way *not* to appear wealthy out of fear that he may receive less support from others.

It would seem, based on the case histories that psychologists cite, that obsession with money is a man's problem. But although more men are seeing therapists for this reason, Jacqueline Plumez senses that, with the ranks of female executives growing, the feverish quest for money is becoming more of "an equal-opportunity problem."

"In some ways, women may have the greatest conflict with making money," says Rohrlich. "In society's eyes, financial achievement is not fully satisfying for women. They must also be successful as nurturers."

Two-Step Therapy

Therapy for problems connected with wealth often begins with a family member who wants to work out a related problem, Jacobson says, such as a woman whose husband has become impotent or a child doing poorly in school. Later, the husband or parents may seek help, too.

Therapists help patients to address their insecurities, identify what their money may be substituting for, redefine their goals and find more gratifying ways to achieve them.

"I don't tell these people that making a lot of money isn't good. If I did, they'd think I was crazy," says Jacobson. Rohrlich stresses that an interest in making money isn't always a clinical pathology. "It can be a normal state of affairs." ■

–Amy Wilbur and Don Antrim

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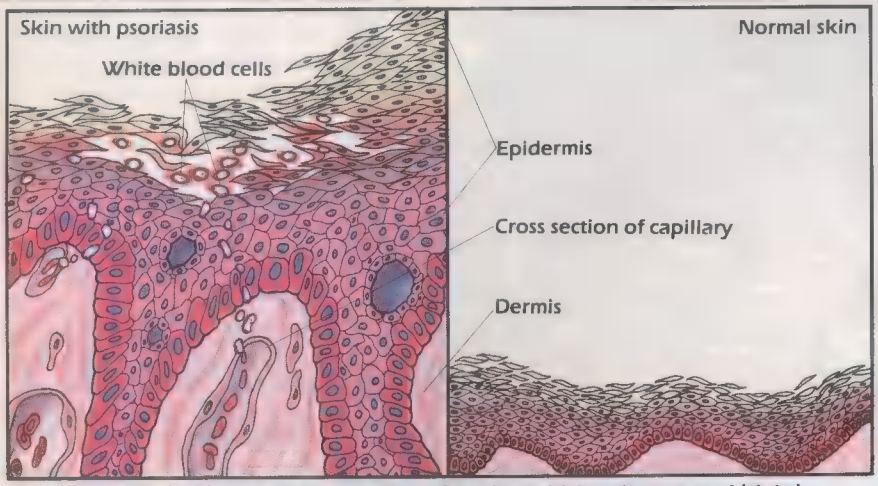
The Attack on Psoriasis

For millions, new treatments mean relief from the heartbreak.



In psoriatic skin (left) the epidermis is about four times thicker than normal (right). Capillaries in the dermis swell, releasing white blood cells, which cause the lesions.

All skin diseases leave a psychological as well as a physical mark on their victims; psoriasis, however, compounds these liabilities by often remaining unresponsive to treatment. Six to 8 million Americans have psoriasis, whose chronic dry, scaly lesions cover elbows, knees, back, scalp, genitals and, in severe cases, even the entire body. According to dermatologists, patients often drop out of school or fear being seen naked, even by their spouses.

The search for an effective treatment has been frustrated by a lack of information about the disease. Although it seems to be inherited and its symptoms can be brought on by stress, infections, nervous disorders or even a dry climate, no one knows what causes psoriasis. Nevertheless, two new treatments have succeeded in achieving long-term remission.

Psoriasis makes the cells in the basal layer of the epidermis—the outermost skin layer—divide abnormally quickly. New skin cells travel to the surface in only four days, rather than the usual month, building up as dry, white flakes. White blood cells migrate to the upper layers of the epidermis and form the plaquelike lesions that last for months or years.

Traditional treatments include mineral baths, which temporarily alleviate the plaque's dryness, and steroid hormone creams that inhibit cell growth. When these fail, shortwave—type B—ultraviolet light usually gets results by slowing cell growth.

A relatively new, more effective ultraviolet-light treatment uses long-wave, type A, light with methoxsalen, a drug that accelerates the skin's reaction to the light. In use for three years, this therapy, called PUVA, clears up psoriatic lesions in about 88 percent of the patients. It is more successful than any other treatment.

Two-Year Remissions

Using PUVA, dermatologist Samuel Mandel of New York City has helped patients stay in remission for as long as six years. Usually, however, remission with PUVA lasts for a year or two. The number of treatments needed to clear the skin varies from 4 to 20, and each session lasts from a few minutes to an hour.

Although long-wave ultraviolet light is less damaging to the skin than shortwave, studies at Harvard and in Australia link PUVA treatments to an increased susceptibility to skin cancer.

Another new treatment, reported in the *New England Journal of Medicine,* is so simple that it was discovered by accident. After removing a psoriatic skin sample from the elbow of a woman for a biopsy last year, dermatologist Ronald Shore of Johns Hopkins covered the sutures with a Band-Aid. When the woman returned three weeks later, the areas beneath the adhesive tape had become completely clear of psoriasis.

Afterward, in tests with several psoriasis patients, Shore found that adhesive tape partially cleared most lesions and eliminated some for a month or longer.

"The fact that the tape works not only may offer possibilities for a new and safe treatment," he says, "but it may be telling us something new about the disease itself." He speculates that skin-cell replacement rates may be controlled in part by hydration. Since psoriatic lesions lose water much faster than healthy epidermis, adhesive tape, which inhibits water loss, may clear the lesions without drugs or ultraviolet light. ■

–John Sullivan

Herpes Vaccine Passes Test

First to bar latencies

When the herpesvirus invades a body, it lies dormant in the nervous system, where it can be reactivated, causing painful lesions. It has also been linked to cervical cancer. For the first time, a genetically engineered vaccine, tested in mice, prevented the herpesvirus from entering the nervous system and becoming latent, according to a report in *Science.*

"This is an early step toward developing a human vaccine," says herpesvirus specialist Abner Notkins, of the National Institute of Dental Research, whose group performed the tests.

Bernard Moses and colleagues at the National Institute of Allergy and Infectious Diseases used the gene of an oral herpesvirus surface protein, the part of the virus to which antibodies bind, and spliced it into a carrier virus, vaccinia. The surface protein, glycoprotein D, stimulates the invaded organism's immune system.

Mice injected with the vaccine produced immune responses that protected almost all of them against lethal doses of oral and genital herpesvirus and two-thirds of them against a viral invasion of the nervous system. Notkins speculates that protection "depends on whether or not the antibody inactivates the virus before it enters the nervous system."

The researchers are now testing how long the vaccine stays potent; it may be ready for use in four or five years. ■

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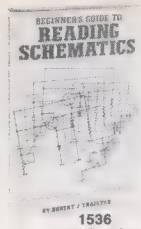

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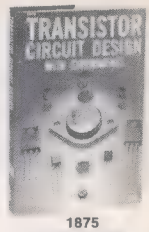

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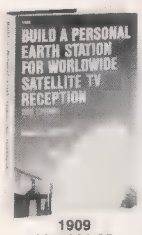

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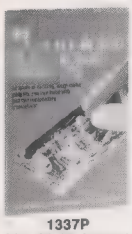

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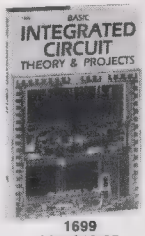

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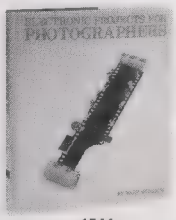

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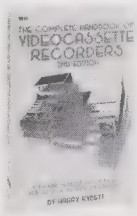

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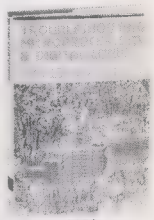

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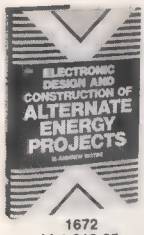

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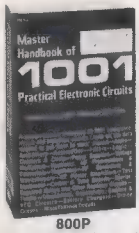

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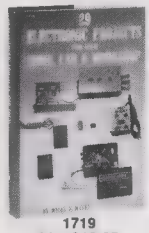

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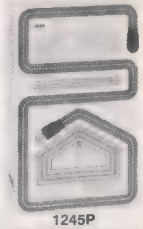

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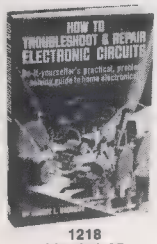

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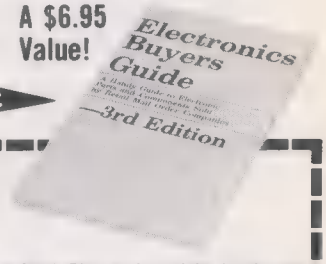

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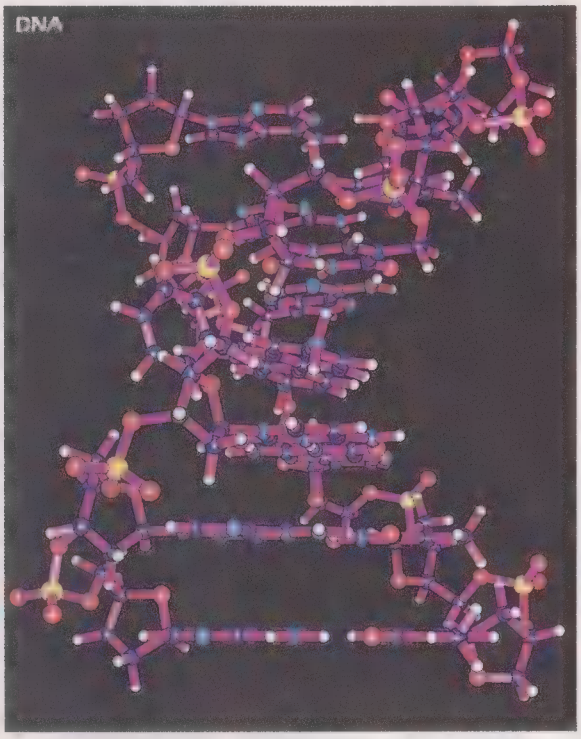
Better Drugs by Computer

As techniques mature, designing medicines takes a quantum leap.

For people who have untreatable diseases or who must take drugs with serious side effects, waiting for new medicines to reach the market can mean the difference between life and death. It takes 7 to 10 years to develop a new drug, and of every 10,000 compounds synthesized, only one will end up on the pharmacy shelf.

This lag time is being shortened by computer programs and sophisticated new computer graphics that are helping chemists design drugs at major pharmaceutical companies around the world. Tony Hopfinger, director of medicinal chemistry at G. D. Searle & Company, in Skokie, Illinois, thinks computers have the potential to make designing drugs four times as efficient as it is today. The first of these new medications should be commercially available within five years.



Equations from quantum mechanics can indicate the shapes of molecules used to make drugs. Here, computer graphics in 3-D, constructed from data on ethidium, show that the drug binds to DNA (center), keeping it from replicating.

In any biologically active molecule—one that's involved in biological processes such as replication—structure is linked to function. A molecule's shape helps indicate whether it can bind to a toxin or a receptor on an invading bacterium, then inactivate or kill it. Now, using equations from quantum mechanics and the formulas of new drugs, chemists can predict molecules' shapes. With the data, a computer can generate graphics that show how the drug should behave in the body.

Scientists are aware, for instance, that the compound ethidium binds to DNA and is therefore a good marker for determining DNA content in a cell. "With 3-D computer graphics we could see that under some circumstances ethidium stops DNA from replicating," says Hopfinger, a trait that could be useful in fighting cancer, which is uncontrolled cell replication.

The traditional way of making new drugs is to test the activity of a wide variety of chemical compounds on laboratory animals. But with computers, the structure of a new molecule can be compared with that of others whose activity in the human body is already known. The only compounds tested will be those that are structurally similar to compounds with the desired activity. This is likely to mean that fewer animals will be needed for these crucial experiments.

Better and Safer Drugs

Today, pharmaceutical companies use computer programs primarily "for testing a chemist's hypothesis about a compound's biological activity," says Peter Gund, director of chemical and biological systems at Merck Sharp & Dohme, in New Jersey. Tomorrow, however, computer systems are expected to lead to safer, more effective drugs. Chemists will routinely identify the cross-reactions and side effects of new drugs and, by making some changes in their molecular structure, eliminate the bad side effects while retaining the benefits.

For example, new anticancer drugs would be screened for their potential toxic effects on the heart or liver and for cross-reactions with antibiotics. Because many anticancer medications depress the immune system, cancer patients are given antibiotics to control infections.

Before such drugs can be developed, scientists must upgrade their data on the molecular structure of compounds that are likely to have pharmaceutical value. For now, however, the design process still involves, as Gund notes, "a considerable amount of serendipity." ■

–Barbara Tokay

Animal Virus and Mental Illness

Link found in people

An inscrutable virus that causes nervous and behavioral disorders in animals may be linked to mental illness in people.

The Borna disease virus causes spasms, paralysis and behavioral changes in sheep and horses. Although endemic to Germany and Switzerland, it was never previously reported in animals in the United States or linked anywhere in the world to human illness.

In a recent study, antibodies to the Borna disease virus were found in the blood serum of German and U.S. psychiatric patients, an indication that they have been exposed to the virus. No antibodies were found in the healthy volunteers. The researchers reported their findings in *Science* this spring.

In animals, the Borna disease virus replicates in several cell lines after infecting the brain cells. "We don't know how it's transmitted to humans—or even to animals," says psychologist Jay Amsterdam, one of the researchers. "You can't see the virus under an electron microscope, and it hasn't been classified biochemically."

This is the first evidence of a direct relationship between any virus and mental illness. To substantiate their findings, the researchers are looking for Borna disease virus antibodies in a wide population: clinically depressed people, AIDS victims and others with low immunity. ■

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Age Cannot Wither . . .

Even after 60, exercise can keep you as fit as a 20-year-old.

Last spring, Carlos Lopes ran the fastest marathon in history, covering 26.2 miles through Rotterdam in 2 hours, 7 minutes, 11 seconds, and smashing the former best time by 54 seconds. His pace was faster than most casual runners can maintain for *one* mile.

Carlos Lopes is 38 years old.

In recent years, science has shown that while the body does age, the physical decline is not always dramatic and irreversible. Remarkable findings have resulted from studies of maximal oxygen consumption (VO_2 max), also called aerobic capacity—the body's ability to utilize oxygen. This is the yardstick of fitness most often used by physiologists. Chronological age can be meaningless. Many fit 60-year-olds have higher VO_2 max's than do sedentary 20-year-olds.

Maximal oxygen consumption in the elderly is strongly affected by training. In a highly trained individual who has reached his greatest potential, VO_2 max does decline, but the rate of decline can be slowed drastically. And a sedentary 60-year-old who hasn't reached his potential can *improve* his VO_2 max as much as a 20-year-old can.

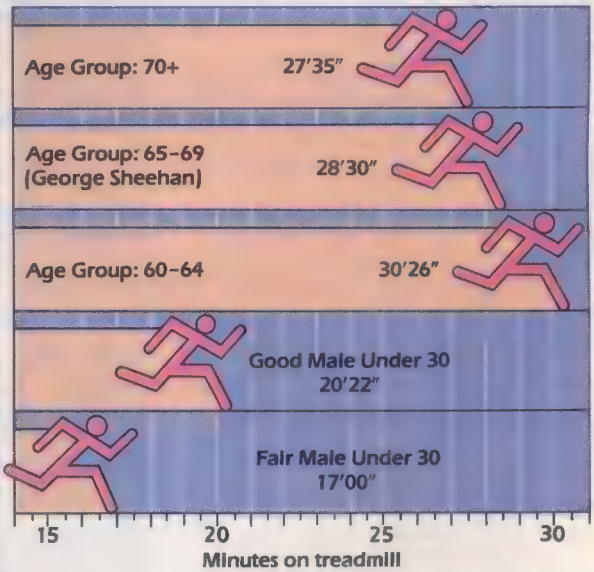
Says cardiologist and world-famous runner George Sheehan, "We have learned that aging is a myth."

George Sheehan, running strong at age 66, says, "We have learned aging is a myth."

Sheehan is entitled to exaggerate. At 61 he ran a marathon in just over three hours—a personal record and an excellent time for a 30-year-old. Remarkably, Sheehan stopped running at age 22 and didn't start again until age 45. Now 66, he has been improving ever since. "Exercise physiologists," he says, "are salivating after us."

VO_2 max (the V stands for volume, the O_2 for oxygen) is given in terms of milliliters of oxygen consumed per kilogram of body weight per minute (ml/kg/minute). It is ultimately a measure of the body's maximum capacity to oxidize glucose to energize contractions of muscle cells. With a greater oxygen-processing capacity, more energy can be released and more work can be performed. A high VO_2 max implies large-capacity lungs, a strong heart, a good supply of blood vessels in the muscles and many mitochondria—the cellular energy factories in which glucose is oxidized.

VO_2 max is typically determined by a treadmill test. As the treadmill speeds up and its slope increases, the subject's inhalation of oxygen and exhalation of carbon dioxide (the by-product of fuel burning) is measured to determine how much oxygen has been processed.



Older athletes stay on the treadmill at the Cooper Clinic in Dallas longer than men half their age manage to.

On a Treadmill at 62

Physiologist Michael Pollock, now the director of cardiac rehabilitation and sports medicine at Universal Services in Houston, conducted research on aging and exercise at Mount Sinai Medical Center in Milwaukee. Twenty-five competitive runners, all over 40, were tested on the treadmill in 1972 and again in 1982 to see how their VO_2 max had fared. Their average age is now 62. Fourteen of the runners had continued logging the same number of miles but had cut back on speed. They experienced a 10-percent reduction in VO_2 max in 10 years. The other 11 had maintained the same distance *and* pace; they experienced no drop. "This finding indicates that if you maintain your training you can significantly retard declines in VO_2 max," says Pollock.

Interestingly, all 25 runners were more fit than the average 20-year-old. The VO_2 max for the elderly athletes ranged from 45.9 ml/kg/minute to 52.5. The average 20-year-old ranges from 40 to 45. Says Pollock, "Age in itself is not a criterion for much of anything."

James Hagberg, an exercise physiologist at the Washington University School of Medicine in St. Louis, has seen similar results in studies of 60 elderly athletes, including Dr. Sheehan. What's more, stroke volume—the amount of blood pumped by the heart with each beat—has not declined. In other studies, Hagberg discovered that sedentary 60-year-olds can increase their VO_2 max by more than 30 percent if they follow a 12-month exercise program that includes walking, jogging and cycling.

Says Hagberg, "Although it is generally downhill with age, you can fight back to a very large degree."

The scientists are only proving what Sheehan has known for years. "We are masters," he says. "We have time to make our bodies into works of art. I tell my audiences, 'I look inside and I don't see wrinkles or a tired heart. I see an unspent youth.' "

–Tom Yulsman

DIAGRAM BY NINA WALLACE; PHOTOGRAPH BY DAVE KINGDON

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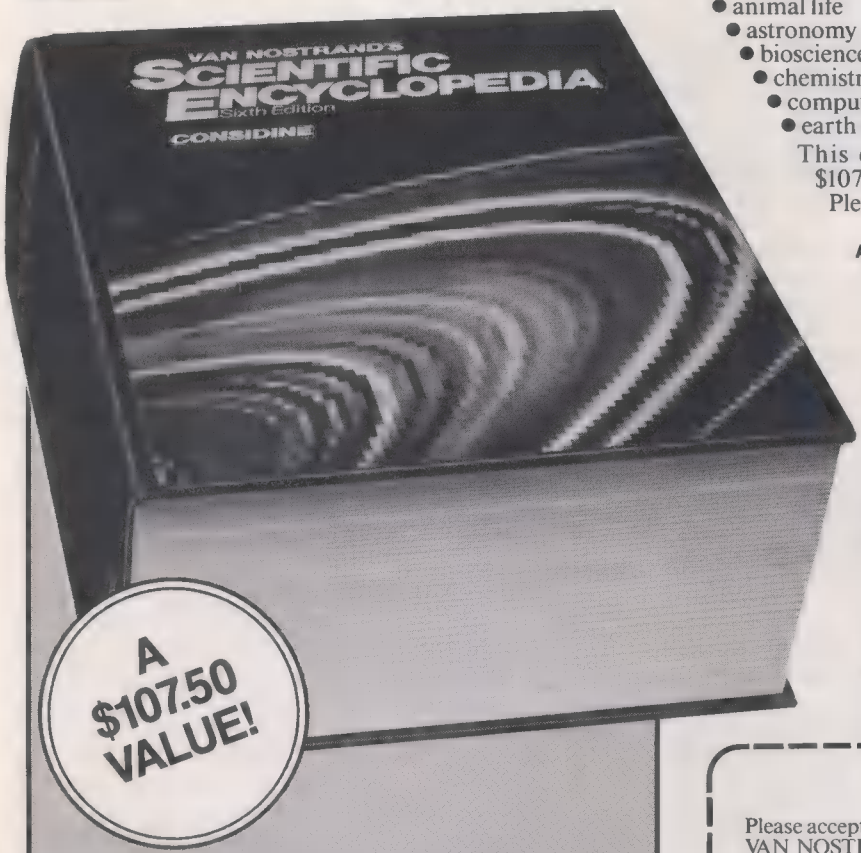

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Science Digest 9/85 2-BD8

The AIDS Controversies

Scientists bicker while their search for a vaccine continues.

Luc Montagnier found an AIDS virus he calls LAV in 1983.

With an increasing number of people in this country now contracting AIDS through heterosexual contact, scientists fear the disease will soon strike thousands of others previously assumed to be risk-free. Although only about 70 such cases have been reported so far, the total number of AIDS patients in the United States now exceeds 9,000 and has been doubling every 12 months. The Centers for Disease Control predicts that in two years the count will reach 40,000.

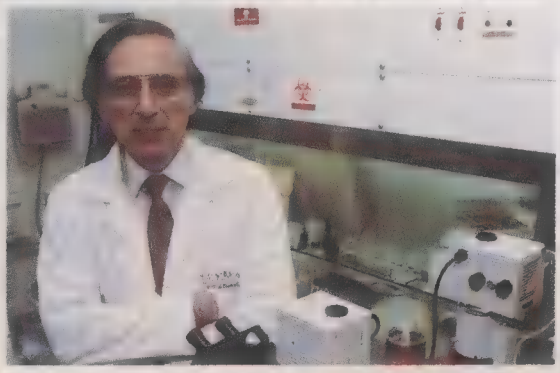
The urgent need to find a vaccine has often been upstaged by concern over who isolated the AIDS virus first—biochemist Robert Gallo, head of the Laboratory of Tumor Cell Biology at the National Cancer Institute in Bethesda, or virologist Luc Montagnier, head of the Viral Oncology Unit at the Pasteur Institute in Paris. Whoever did stands to get millions of dollars in grants and patent rights and perhaps even a Nobel prize. Gallo published his discovery of a virus he calls HTLV-III in May 1984. Montagnier's paper on a virus he calls LAV had appeared the year before.

Based on analyses of the two viruses' genetic sequences, scientists now believe HTLV-III and LAV are variants of the same virus, which seems to throw the contest in Montagnier's favor. Evidence also suggests that Gallo may have misclassified the virus. Proper classification is necessary before scientists can develop a vaccine. Still, the competition persists and was even played out in public last February when Gallo, scheduled to appear with Montagnier at a press conference in New York, failed to show up.

All scientists agree that AIDS is caused by a retrovirus, a class of viruses that alters gene expression in the cells it infects. The AIDS retrovirus attacks and ultimately kills certain white blood cells called T cells that induce immune response. A patient's immunity eventually breaks down, leaving him susceptible to dangerous infections.

Gallo classifies the AIDS retrovirus with those associated with adult T-cell leukemia, HTLV-I and -II, both of which he isolated. Montagnier disagrees because these cancer-causing viruses make T cells multiply uncontrollably, whereas the AIDS virus kills them. In separate experiments, Gallo and Montagnier compared the genetic sequences of the AIDS virus with those of HTLV-I and -II. Gallo reported in a January issue of *Nature* that the three viruses share "structural and functional similarities." Montagnier announced in *Cell*, "The characteristic features of HTLV-I and -II . . . are not observed in the case of LAV."

Montagnier and many other scientists now place the AIDS retrovirus with lentiviruses, slow-acting viruses associated with disease in horses, sheep and goats but not, so far, in humans. The strongest evidence is the similarity of their genetic structure. The "clincher," says virologist Malcolm Martin, of the National Institute of Allergy and Infectious Diseases, is the similarity of their "long terminal repeat," or LTR, the part of a retrovirus that directs the expression of its genes. "I'm convinced," he says, "based on its morphology and structure, that the AIDS virus is a lentivirus."



Robert Gallo isolated HTLV-III, a similar virus, in 1984.

Lentivirus specialist Ashley Haase of the University of Minnesota, collaborating with the Pasteur Institute, recently compared the genetic sequences of the AIDS virus and a lentivirus and found the two "absolutely similar" in size and structure. The results are scheduled to appear in *Cell*. "The AIDS virus is more closely related to lentiviruses than to any other class of retroviruses," he says.

Biologically, both act slowly and can attack the central nervous system. The major difference is that lentiviruses in animals do not cause immunosuppression, but the AIDS virus in humans does. ■

–Susan Gilbert

Probing for Proton Decay

Italians go underground.

Italian physicists are benefiting from a public works project intended to provide jobs for the unemployed. Construction of a pair of tunnels to link Rome and the Adriatic Coast has left the largest hole in the world—a perfect place for physicists to see whether protons decay.

Evidence that protons—building blocks of matter—decay into energy would support the grand unified theories, which say that all the fundamental forces (except gravity) that hold matter together and break it apart are different manifestations of the same force.

By setting up experiments underground, scientists can filter out cosmic radiation, which interferes with the detection of radiation emitted by decaying protons. Typically, caverns are filled with thousands of tons of water, the cheapest medium in which to observe radiation from proton decay. No experiments have yielded definite results, but, according to an article in *Nature*, certain particles formed by proton decay may be too slow to emit radiation in water. Because they got their 100,000-cubic-meter cavern free, Italian physicists hope to splurge on a more refined detector. ■

PHOTOGRAPHS: TOP BY G. RANCINAN/SYGMA. BOTTOM FROM UPI/BETTMANN NEWSPHOTOS

What Color Are Planets?

You probably think you know, but the truth will come as a surprise.

BY MICHAEL D. LEMONICK

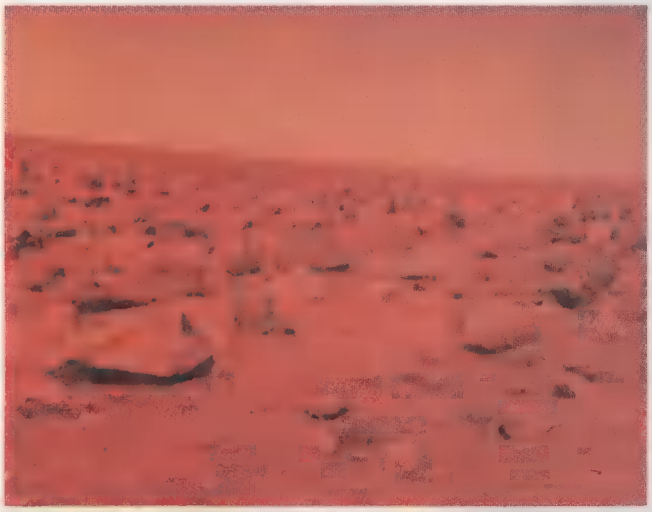
Are we being fooled?

Get ready to have your romantic illusions shattered. The silvery moon isn't silver; it's as dark as parking-lot asphalt. Nor is Mars a reddish orange; it's really a dingy yellowish brown. And Jupiter, far from having magnificent red and orange stripes, is a more uniform pale yellow-green.

The true colors of the planets were revealed by astronomer Andrew Young, of San Diego State University, in an article in the May issue of *Sky & Telescope.* I called Young up to ask why nobody had explored the matter before. "I guess people just haven't thought about it much," he said.

Young says that both our eyes and NASA's cameras—the ones responsible for the spectacular color photos that appear in coffee-table astronomy books—have conspired to mislead us.

The human visual system is overly sophisticated. One definition of an object's true color is what is measured objectively by a physicist's spectrometer; it depends only on the relative amounts of light the object reflects at all the wavelengths of the visible spectrum. That in turn is a function of the kinds and arrangement of the object's component molecules. An object that reflects a lot of 700-nanometer-wavelength light and little else is therefore objectively red; one that reflects only 520-nanometer-wavelength light is green.



The familiar view of Mars confirms what we've always thought; our solar-system neighbor is appropriately called the Red Planet.

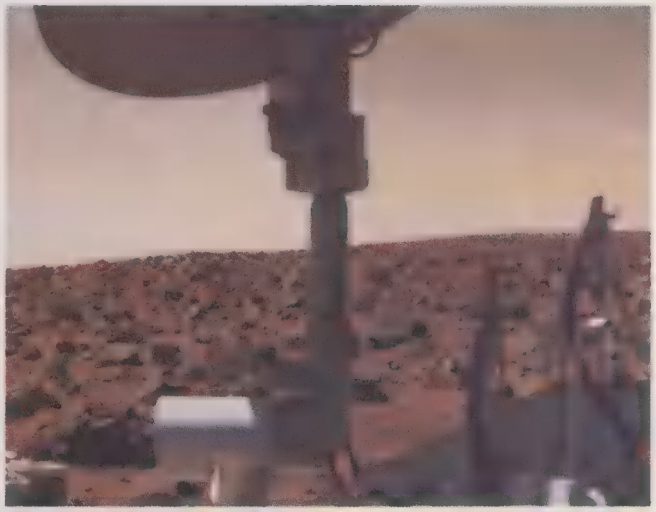
Thanks to the brain's color-processing apparatus, though, the colors we experience are different from those measured by physicists. The brain takes into account its memory of what color an object *should* look; it also factors in the total reflected light.

Young offers an example of the latter effect. Look at a piece of chocolate and a piece of orange peel. We would obviously call them different in color. Yet an objective analysis reveals that both reflect the same mix of light wavelengths. The only difference is that the chocolate reflects a smaller amount of light under a given level of illumination—again, due to its molecular structure. Compare a dimly lit orange and brightly lit chocolate, and they'll look the same.

Now take Mars. A spectral analysis reveals that its mix of reflected light makes it approximately the same color as the orange—or the chocolate. Which one we perceive should be determined by its brightness. This is just the point, though, where our brains fool us. Mars reflects about the same amount of light—is about as bright—as a piece of chocolate. But seen against the black backdrop of space, Mars *looks* relatively brighter. The brain says, in effect, "it's bright, so it's orange." The same effect colors our view of the moon. It's dark gray; against space, it's silvery gray.

How to Make Io Look Like a Pizza

Young himself started to wonder about the topic when he saw the first close-ups of Io, the Jovian moon closest to the giant planet. "The picture showed Io as being red," he says. "It's now called the pizza photo. But I'd seen Io through a telescope, and it looked pale yellow. I checked into it and found that there was no color reference card aboard *Voyager* to test the camera's accuracy. Actually, the image-reproduction system worked in such a way that all colors were shifted toward the red end of the spectrum."



The photograph to the left, though, has been processed to appear lighter than it really is. Mars is in fact brown, as seen above.

The problem was compounded in pictures of Jupiter and Saturn, taken by the same cameras. "The people at the Jet Propulsion Lab wanted to emphasize different features in the planets' atmospheres," he says, "and they also wanted to publish pictures that would look good in the media. So they processed the photos through a computer, making the dark areas look darker."

Lest you think all is illusion, though, there's one planet that really is the color we think. Earth, as seen from outer space, is, over most of its surface, a rich, bright blue. ■

Senior writer Michael Lemonick writes frequently about astronomy and related topics and welcomes your questions. Please send them to: Astronomy, Science Digest, *888 Seventh Ave., New York, NY 10106.*

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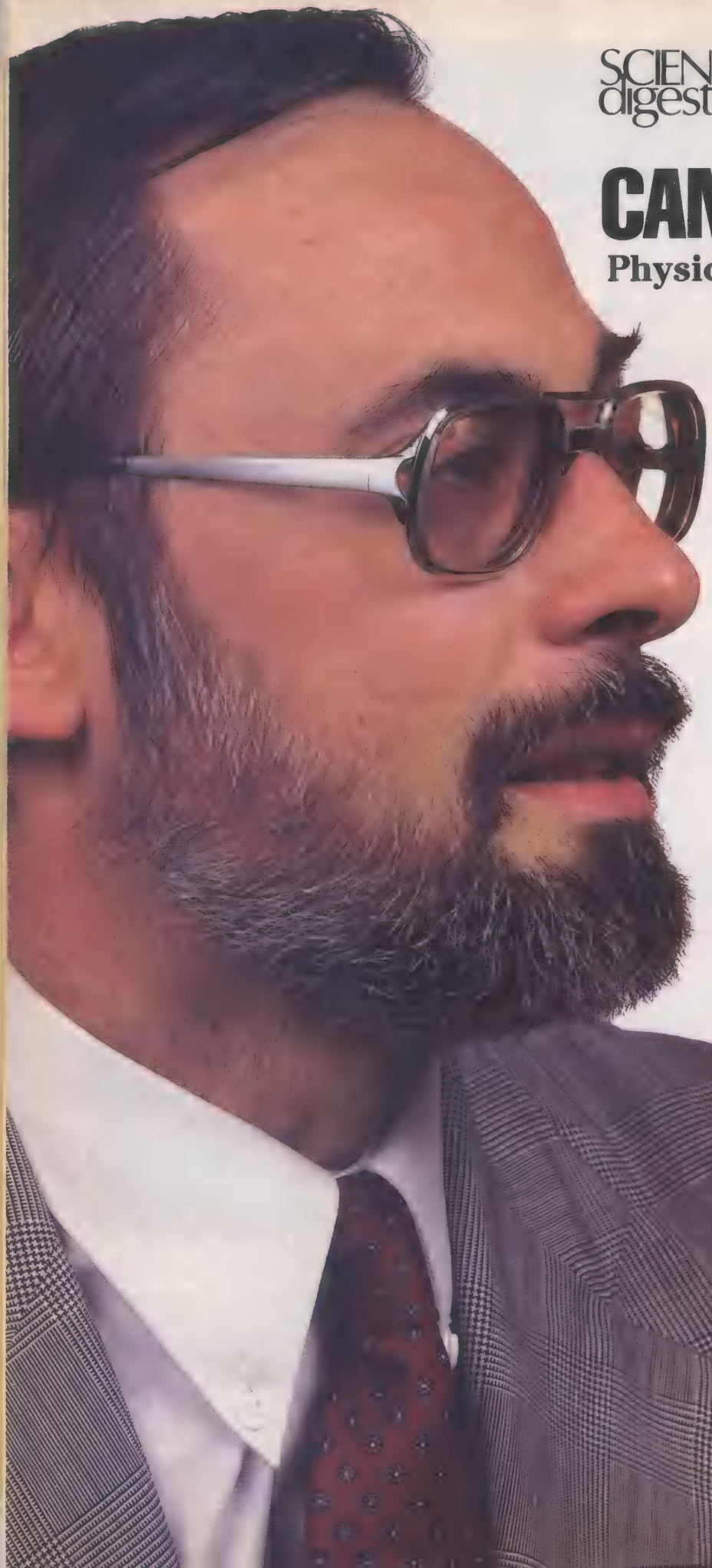
SCIENCE digest

CAN STAR WARS

Physicists debate the merits of



BY GEROLD YONAS

Yes...

IN HIS WIDELY PUBLICIZED speech of March 23, 1983, President Reagan launched "an effort which holds the promise of changing the course of human history." Having posed the question, "Would it not be better to save lives than to avenge them?" he called upon the scientific and technical community to establish a comprehensive effort to define a research program aimed at eventually eliminating the threat posed by nuclear-armed ballistic missiles.

The President caught many people by surprise, and we find even now, some two years later, that many people still think he called for development or deployment or even an upgrading of a defensive system that they mistakenly think already exists. The fact is that he called for a research program, and we have no deployed system with which to respond to a ballistic-missile attack. The surprise to most people is that we have intentionally placed ourselves in a situation where our only responses to an attack are to either retaliate or surrender, but not protect ourselves.

To understand this, one must consider that the existing 1972 ABM (Antiballistic Missile) treaty was built on the expectation that if both sides

Gerold Yonas is the Chief Scientist and the Acting Deputy Director of the Strategic Defense Initiative Organization. Prior to his appointment to SDI, he was the Director of Pulsed-Power Sciences at the Sandia National Laboratories, where he directed development and application of intense ion and electron beams, high-power microwaves, lasers and energy-conversion devices. A graduate of Cornell, Dr. Yonas earned his Ph.D. in engineering sciences at Caltech.

PHOTOGRAPHS BY LEONID LUBIANITSKY

MAKE US SAFE?

the President's defense plan.

BY HANS A. BETHE

No...

THE STRATEGIC DEFENSE INItiative (SDI) is intended to provide a comprehensive defensive shield for the United States and its allies against a nuclear attack; it is supposed to "render nuclear weapons impotent and obsolete." At first glance, this certainly appears to be a desirable goal.

Because of the immense destructive power of nuclear weapons when used against people and cities, and because of the very large number of nuclear weapons the United States and the Soviet Union now have, the degree of perfection required of such a defensive shield is truly staggering. The shield must be capable of intercepting and destroying thousands of ICBMs, SLBMs, cruise missiles and bombers within minutes or even seconds. The intercepts have to be made at sufficient range and altitude to prevent damage from "salvage fuzing"—a term referring to the capability of an ICBM to "sense" when it is being attacked and, upon recognition, being able to detonate its own nuclear explosive. Thus, if such an ICBM is attacked 3 to 12 miles above a city, its nuclear explosion will still do major damage. The number of attacking weapons can be in the range of 10,000; therefore a failure rate of even

Hans A. Bethe, vigorous spokesman on the control of nuclear armaments, was awarded the Nobel prize in 1967 for his discovery of basic ideas about thermonuclear reactions in stars. Now professor emeritus of physics at Cornell, Dr. Bethe was an original member of the team that built the first atomic bomb in 1945. He wrote this article with Dr. Fredrik Zachariasen, now a Caltech physics professor and formerly Associate Director of Los Alamos National Laboratory.

Yonas

remained mutually vulnerable to attack, then this mutual vulnerability would reduce incentives to further build up strategic offensive forces. We found, however, that the Soviets have quadrupled their nuclear warheads in the past 15 years and have emphasized high precision and rapid response, which make our Minuteman missiles and other military assets vulnerable to a first strike.

It also became increasingly obvious that the Soviet Union had never rejected its own protection and was investing heavily in strategic air, civil and ballistic-missile defense while pursuing a full range of strategic weapons. It is continuing its tests of the world's only operational antisatellite system, improving its conventional ballistic-missile defense capability around Moscow and completing a large phased-array radar facility at Krasnoyarsk in violation of that 1972 treaty. It is, in addition, making large investments in advanced long-term research, such as that needed for ground-based lasers, particle beams and beam-weapon power supplies. In addition, its continuing investment in antitactical (short range) ballistic missiles points to the possibility that it is establishing the necessary infrastructure for rapid deployment of a nationwide defense system.

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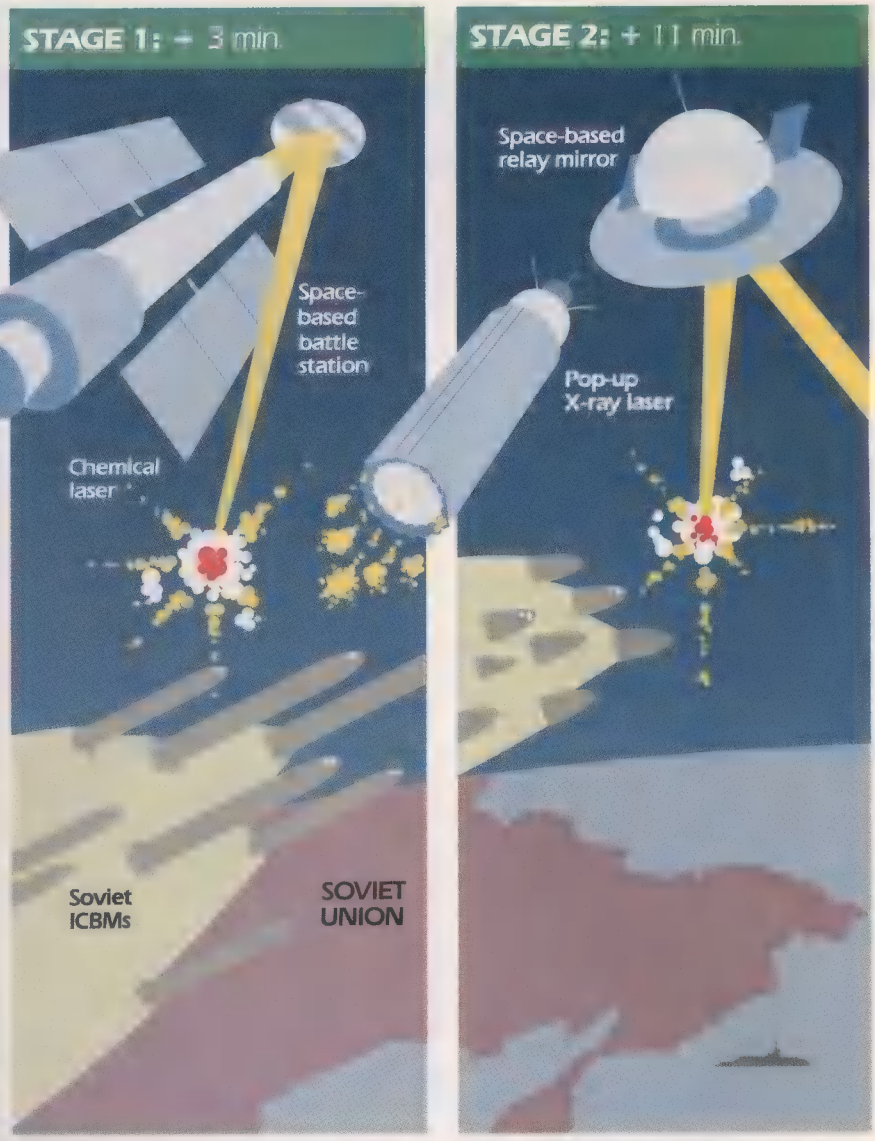


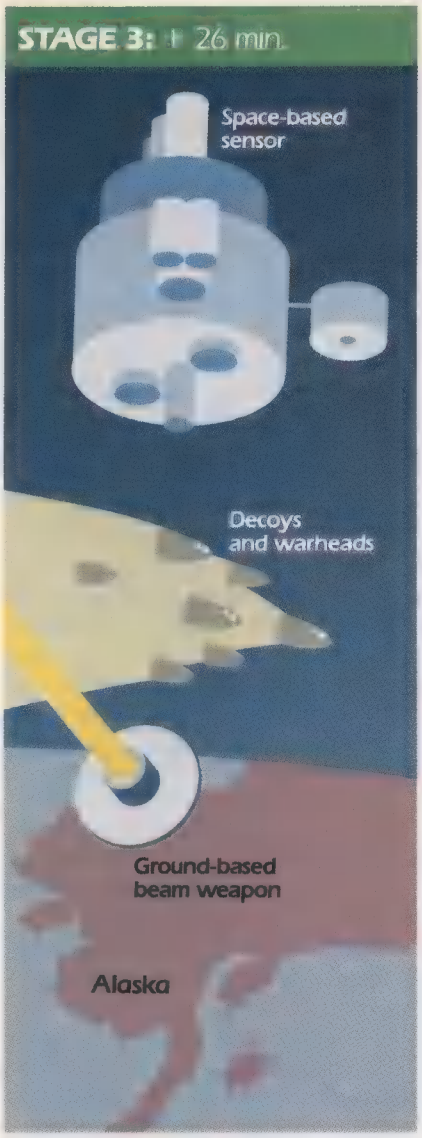
In boost phase, exhaust heat from 1,000 Soviet ICBMs is detected by surveillance satellites; space-based battle stations, utilizing chemical lasers, are alerted by computer and have three minutes to destroy the missiles before they deploy warheads.

As the ICBMs rise to busing phase, they release actual warheads and decoys. A "pop up" X-ray laser, launched by a sub-based missile, and space-based relay mirrors, reflecting a ground-based laser, have 11 minutes to distinguish between the two.

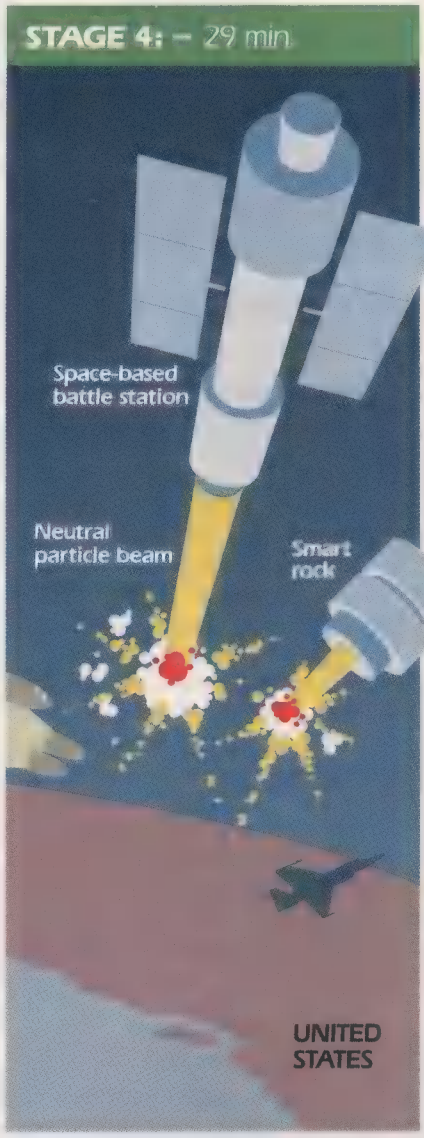
DIAGRAMS BY BERGMAN HAKE DESIGN

In contrast to the obvious Soviet commitment to defense, the United States has been pursuing an inadequately supported effort in ballistic-missile-defense (BMD) research. Although we have had an ongoing effort since we signed the treaty, the program has suffered from a lack of definition, technical strategy and goals and could be characterized as consisting of starts and stops that seem to cancel themselves. Despite rather substantial expenditures, the full potential of our ballistic-missile-defense research has not been realized. In addition, our research and development has advanced considerably, in many cases totally independently of the BMD effort, but the nation has not been putting this new capability into acquiring the maximum return on its BMD investments.

BMD has been largely a back-burner issue in the United States since the ABM treaty. Although most people had lost sight of the issue or thought we had retained some deployed capabilities, some people were aware of the problem and were advocating a move away from the sole reliance on the threat of retaliation to deter an attack. Senator Malcolm Wallop had been proposing since the late 1970s a crash program to develop space-based chemical lasers as a missile defense. Army Lieutenant General Daniel Graham, a former director of the Defense Intelligence Agency, had actively advocated a defense plan using hundreds of orbiting platforms carrying sensors and small rockets to launch homing projectiles at missiles. In addition, Dr. Edward Teller was urging that the President increase support of nuclear-driven, directed-energy weapons that would harness the enormous energy of nuclear explosives to destroy attacking missiles.



Decoys and warheads soar into mid-course phase, where they are tracked by space-based sensors and battle stations. If only 10 percent of the reentry vehicles survive, weapons must disable 12 targets every second to shield the United States.



In the terminal phase, 29 minutes after launch, reentry vehicles near the targets. Space-based particle beams and kinetic-energy weapons (smart rocks) will seek to destroy the RVs while they are still high enough not to threaten cities.

Bethe

one in 1,000 on the part of the defense permits a huge amount of damage. And the defense must be able to accomplish all of this in the face of an imposing array of countermeasures available to the attacker.

The requirements for a defense intended to defend population and cities are very different from those of the "hard-point defense" systems that have for years been the subject of research by the U.S. Army (although the United States has never actually deployed such a system). Hard-point defense is primarily designed to protect missile silos from nuclear attack. Missile silos are targets that can withstand a one-megaton explosion at a distance of only a few hundred yards, so the defense can operate at short range and low altitude. Further, since the purpose of the hard-point defense is only to guarantee the survival of a sufficient number of missile silos to constitute a deterrent, it does not have to protect each individual silo very well; a reasonably high "leakage rate" is quite acceptable. It is generally accepted among experts that a defense of this sort is probably technologically feasible, either right now or in the near future.

□

Hard-point defense is simply a means of enhancing deterrence, in that it helps to protect the retaliatory forces against a possible disarming first strike. It cannot threaten the opponent's deterrent. This kind of defense, therefore, entails no basic policy change from the present. However, its introduction would require a major amendment to the existing treaty against ABMs (antiballistic missiles), hence negotiations with the Soviets. If it were made part of a negotiated treaty, it could further stabilize the existing situation.

By contrast, comprehensive defense of people and cities involves a fundamental change in strategic policy. It would not contribute to the present mutual-deterrent posture; if it existed it would deprive the opponent of his deterrent. An opponent, of course, would view that as a strategic disaster; he would be vulnerable to any action by the side possessing the defense. Obviously, he could not willingly allow himself to be put in such a position and would be forced to attempt to nullify the defense by modifying and augmenting his offensive forces.

If someday a near-perfect defense were simultaneously achieved by both sides, then there might be a balance based on defense—one that would be as, or even more, stable than the one we have now based on mutual deterrence. But the transition from our current situation, in which offense dominates, to one in which defense dominates must of necessity pass through a very long phase in which the defense is only partially effective. This transition period would be a time of great strategic instability. A partial defense is likely to be far more effective against a small attack than it is against a large one. In a crisis situation there is therefore a premium in shooting first. If you shoot first, and destroy a reasonable fraction of your opponent's retaliatory force, perhaps your partial defense can cope with the remainder. But if he shoots first, then

"The Soviets were spending as much on strategic defense as on offense."

Yonas

Many of us realized that the technology had progressed far beyond the capabilities of the late 1960s, and a new and comprehensive look at the prospects for BMD was a prudent, long overdue step.

Our hopes and expectations that the ABM treaty would lead to strategic arms limitation had been shattered by the realization of the inexorable buildup in Soviet forces. At the same time, we were faced with the fact that, in contrast to our neglect of defense, the Soviets were spending as much on strategic defense as on strategic offense. The President's call to the technical community was the first sign that we might change our course if the community could provide the convincing factual basis to support a decision to move in a new direction.

The next step occurred in April 1983, when the President signed a directive mandating two intensive studies that would develop a plan of research fully consistent with the 1972 ABM treaty and explore policy strategies related to these technologies. The purpose of the technology program was to explore a wide range of concepts and technologies that hold potential for a reliable and effective BMD. The Defensive Technology Study Team (DTST), headed by former NASA Administrator Dr. James Fletcher, produced its report in the fall of 1983 after an intensive review of past work and the full range of proposals for future research. The team consisted of over 50 experts drawn from industry, government, universities and national laboratories. The team represented a wide spectrum of opinion on BMD and fully considered not only the defense approaches but also myriad possible countermeasures to defeat the defense. There was special emphasis on the all-important issue of estimating the cost of various approaches and comparisons with possible costs of countermeasures.

The team agreed from the start that there would not be a "perfect" defense against a determined adversary, but they were instead striving to identify options that would be sufficiently effective and affordable to make a first strike of no military significance (enhance crisis stability) and to so devalue any offensive response (support arms-race stability) to motivate a move toward substantial reductions in armaments.

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The DTST chose to adopt a high-payoff, long-range emphasis rather than to identify near-term capabilities that might be more easily attained but might in turn be more easily countered. The research program would emphasize the limits of technologies, not just for the defense but also for the offensive countermeasures. The team decided that the decision process would have to start with a broad range of technologies and approaches, which would then be winnowed down to a concentrated emphasis on a more manageable set, following such criteria as the ability to stay ahead of responses at an affordable cost.

A resolute opponent would attempt to defeat a defense system with countermeasures that might range all the way from directly attacking the defense to massive proliferation of existing weapons. The key was to identify technology options that could advance faster and at a lower cost than the offensive responses. The DTST was fundamentally optimistic about the technologies in the light of the spectacular advances that had taken place over the past two decades in the technologies of sensors, computing hardware and software, optics, beam weapons and propulsion. The team could not foresee fundamental limits in many areas, and in view of the full range of options, there was a general belief that even if certain approaches were eliminated, the overall defense requirements could be met.

The report of the Defensive Technology Study Team was submitted to the Department of Defense in October 1983. In March 1984, the Secretary of Defense announced the establishment of a new program reporting directly to himself. This program is called the Strategic Defense Initiative (SDI), and Air Force Lieutenant General James Abrahamson is its director. The Strategic Defense Initiative Organization was charged with developing and implementing a research program for defense against ballistic missiles, incorporating ongoing defensive activities together with the new ones proposed in the study report.

The program designed by the DTST is a long-term effort in four phases. The first phase, lasting until the early 1990s, will consist of research. At that time, decisions could be made on whether to begin engineering development of specific weapons. The second phase would focus on systems development, when prototypes of actual defense components would be designed, built and tested, assuming a decision is made to go ahead with this defense. The third phase would be a transition period, with incremental, sequential de-

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PHOTOGRAPHS BY LEONID LUBIANITSKY

"The perfection required of such a defensive shield is truly staggering."

Bethe

your remaining forces may not be strong enough to overcome his partial defense; you are destroyed and he survives. In a situation of great tension, there would be immense pressure on each side to shoot first, because of the fear that the other would. In a world without a defense, and with an invulnerable deterrent, such as we have now, no such pressure exists; each side can afford to wait the crisis out.

All of these are old arguments, of course. All of them were debated repeatedly during the first ABM debate, prior to the advent of the ABM treaty in 1972. They are just as valid now and will remain so until some far-off Utopia (which may never be reached) in which both sides possess a near-perfect defense.

At present, ICBMs are launched from silos at known locations, though the Soviets will apparently soon deploy new mobile ICBMs that can be launched from railway cars and from trucks. After launch comes "boost phase," during which several stages of rocket motors accelerate the missile onto its ballistic trajectory. Boost phase, with the present ICBMs, lasts several minutes and ends when the missile is at an altitude of several hundred miles, well above the atmosphere. Once the rocket motors burn out, up to 10 independent warheads, or "reentry vehicles," are separated from the missile and travel on independent trajectories to their targets. At this time, decoys, balloons, radar-and-optics-reflecting chaff and other means of confusing a defense can be dispensed as well. The next phase is called "mid-course"; during this period the collection of separate warheads and decoys travels above the atmosphere in unpowered flight. Mid-course typically lasts 20 minutes. Finally, the objects reenter the atmosphere and head toward the ground in the "terminal phase" of their flight. Upon reentering the atmosphere, at an altitude of around 60 to 90 miles, air friction removes chaff and light decoys such as balloons, leaving real warheads and heavy decoys exposed. The initial velocity upon reentry is around four miles per second; depending on the aerodynamic qualities of the reentry vehicles, they slow down but can still be traveling at a substantial fraction of this speed upon reaching the ground.

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Ballistic missiles launched from submarines, called SLBMs (submarine-launched ballistic missiles), differ from land-based ICBMs primarily in that their launch points are not known ahead of time. The missiles only become observable when they break through the sea surface. Since they can be launched much closer to the target, their total flight time can be considerably less than land-based ICBMs require, often as little as 10 minutes.

Cruise missiles can be launched from airplanes, submarines or the ground. They are basically very small jet aircraft and travel subsonically at an altitude of only a few hundred feet. Since they are small and hug the ground, they are hard to detect by radar. They are, however, slow, allowing the defense considerable time to cope with them.

The last strategic-nuclear-weapon delivery system is bombers, which, for practical purposes, one can think of as large cruise missiles. They are also slow and fly low; but they can, in principle, defend themselves.

To design an effective defense against all of these methods of delivering nuclear weapons requires using a large variety of techniques. The part of the problem that has attracted most public attention and controversy is defense against ICBMs.

Technically, the easiest phase of an ICBM's flight for a defense to exploit is the terminal phase, for it is here that decoys and chaff have been stripped away, and the defense can use short-range interceptors. It is for this reason that the Army's hard-point terminal defense is nearly irrelevant in the context of the SDI, because intercepts take place at too low an altitude to protect soft targets such as cities and people against salvage fuzing. So the SDI must concentrate on boost phase and mid-course. Of these two, boost phase is more desirable because the separate reentry vehicles and decoys have not yet been dispensed, and hence there are fewer targets to be attacked; in addition, boosters are soft and easily detected. But boost phase lasts a relatively short time and takes place over the attacker's territory, requiring the defense to be either space-based or to have some means of getting rapidly into space beyond the attacker's boundaries. Conversely, during mid-course the defense has more time and can get reasonably close, but it has to contend with already separated and hard reentry vehicles that it must detect among thousands of decoys.

Destroying anything requires delivering energy to it. To destroy an ICBM booster in boost phase requires delivering sufficient energy over a distance

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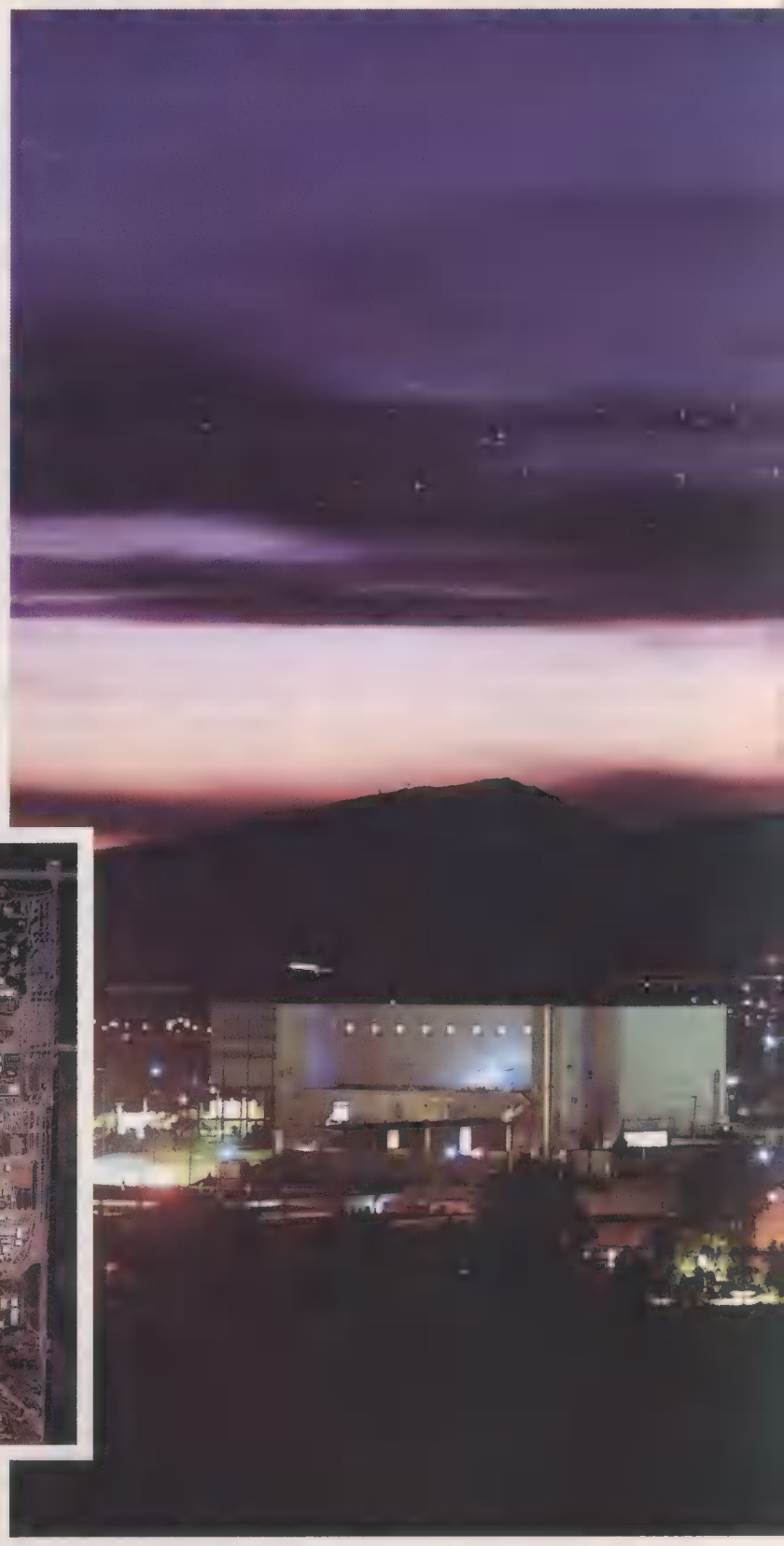
STAR WARRIORS A visit to the

BY WILLIAM J. BROAD

May 1984: I was deep into a week of roaming among the young warriors. They had graduated at the top of their classes from some of the most competitive universities in America. Now they worked at the Lawrence Livermore National Laboratory, a federal facility for the design of nuclear weapons in a dry valley about 40 miles east of San Francisco. Theirs was a world of blue jeans, Coke bottles and top-secret research that took place six or seven days a week, often all night long. Their labors had helped inspire President Reagan's Star Wars speech and were now aimed at bringing that vision to life. Their goal was to channel the power of nuclear explosions into deadly beams that would flash through space to destroy enemy missiles. They labored not only on weapons but on supercomputers, communications devices and other vital links for the creation of a defensive shield. And they talked late into the night about how to use their futuristic inventions.

I had come to the lab with some apprehension. After all, while these scientists were celebrating the energies of youth with nuclear breakthroughs, many young people around the world



PHOTOGRAPHS, LEFT, COURTESY LAWRENCE LIVERMORE NATIONAL LABORATORY/UNIVERSITY OF CALIFORNIA. RIGHT, BY HARALD SUND

A nondescript fortress nestled in the East Bay foothills of San Francisco, Lawrence Livermore glows through the night as its intense young scientists race to bring President Reagan's SDI concept to a working reality.

eerie world of Lawrence Livermore's weapons designers.

The warriors say that Livermore's bombs are the way "to send the very best."

were calling for a nuclear freeze. But the warriors turned out to be anything but humorless automatons. They played pranks, swapped stories and relished the fun of a community that resembled an extended family. Many professed concern about the future of their country. At times they seemed almost too wholesome: None of them smoked. Their worst addictions seemed to be the consumption of soft drinks by the case and the ingestion of large amounts of ice cream. Most striking, they were charged with enthusiasm for their common goal of using their technical advances to protect the nation from the horrors of nuclear war.

But their excitement also had a dark side. They could be arrogant. At times they seemed to believe that their labors gave them the power to save or destroy the world. They enjoyed black humor. Mimicking a greeting-card slogan, they liked to say the bombs of Livermore were the way "to send the very best."

Livermore is one of two federal facilities in the United States for the design of nuclear weapons. It makes no production-line warheads. Instead, the weapons are imagined, sketched on blackboards and modeled on computers. Months or years can pass before Livermore decides to build a prototype and ship its parts over the Sierra Nevada mountains for assembly at a government-owned patch of desert in the neighboring state of Nevada. There it is exploded deep underground in a carefully monitored test. If the weapon is a success, its blueprints may be distributed to the various factories around the country that make warheads for the nation's bombers, submarines and silos.

All the weapons labs and production plants are owned by the federal Department of Energy, a civilian agency whose predecessor was the Atomic Energy Commission. Even though the warheads are meant ultimately for the military, their production and design is kept in the hands of civilians, a safeguard established by Congress in the earliest days of the nuclear era.

The first weapons lab in the United States was Los Alamos, built high in the mountains of New Mexico during the exigencies of World War II. Part of the Manhattan Project, it gave birth to the first nuclear weapon.

The second one was Livermore, which was carved out of an abandoned naval air station near the sleepy town of Livermore, California, in 1952. Today the lab employs nearly 8,000 people and has a budget of more than $800 million a year.

These two labs were the start of a big industry. In the United States, the development, production, storage and planning for the use of nuclear weapons involves well over 200,000 people and an annual budget of more than $35 billion, according to Thomas Cochran and the coauthors of the *Nuclear Weapons Databook.* Every day about eight new warheads roll off the assembly line. Old weapons are also retired, but the overall direction of the so-called stockpile is up. There are currently 26,000 warheads in the American nuclear arsenal. By 1990, there are expected to be 32,000.

A few tall structures stood out at Lawrence Livermore. But mostly it was a blur of hundreds of low buildings, trees, roads and parking lots—nearly 8,000 souls practicing their high-technology arts in the middle of nowhere.

Off to the left was the nuclear laboratory, its site in effect a fortress surrounded by mountains. According to geologists, the lab stood amid the Diablo range of the California coastal system. To its south and east was a subsidiary range, the Hamilton, and to its west the Bay Hills. A few miles north of the lab was Mount Diablo itself, a huge mass of rock topped with thick vegetation.

Near the laboratory's main gate,

Lowell Wood:
A protégé of Edward Teller, the 42-year-old leader of O group is a driving force behind the team working on third-generation-weapons ideas

Tom Weaver:
The 34-year-old physicist heads the R program, a spin-off of O group that works on concepts involving development of X-ray laser weapons

PHOTOGRAPHS COURTESY LAWRENCE LIVERMORE NATIONAL LABORATORY

From Star Warriors, *to be published in October by Simon & Schuster.* © *William J. Broad.*

Broad is featured in Contributors, on page 6.

Their weapons would fire radiation through space at the speed of light.

bright streetlights illuminated nearby signs. "No Trespassing," read one. "Trespassing and Loitering Forbidden by Law," warned another. Beyond them was a fence topped with barbed wire; farther still, the dim outlines of darkened buildings.

As I pulled into the lab's entrance, a squat wooden building was on my left, where I had picked up my identification badge earlier in the week. On the right as I drove toward the checkpoint was a large blue sign. "Prohibited items," it warned, included "guns, explosives, binoculars, telescopes, radio transmitters, recording equipment and alcoholic beverages."

I stopped at the checkpoint, a small kiosk containing a guard with a gun. I held out my badge for inspection. The guard touched it. I was waved through.

The force behind the founding of Livermore was Edward Teller, a principal developer of the H-bomb. He lobbied passionately in Congress and the Pentagon for a second nuclear lab. The site was named after his good friend and the laboratory's cofounder, Ernest O. Lawrence, a Nobel laureate who ran the radiation laboratory at the University of California, Berkeley.

The young men and their peers at Livermore have been laboring to carry on Teller's legacy of innovation. Their weapons, hailed as a third nuclear generation, are much more specialized and precise than the previous two generations, the atomic and hydrogen bombs. In weaponry, the steps between eras represent a thousandfold increase in explosive power—a ton for TNT, a kiloton for fission and a megaton for fusion. Powered by A-bombs and H-bombs, third-generation weapons take the explosive energy at their core and channel much of it toward targets rather than letting it escape in all directions.

The key designs of the young warriors number perhaps a half dozen in all. But the details of only one had slipped through the barrier of government secrecy that surrounds all aspects of nuclear design. This was Peter Hagelstein's invention—the nuclear X-ray laser, which produced a powerful beam of radiation. Teller had taken the news of the X-ray breakthrough to President Reagan, who a few months later gave his Star Wars [Strategic Defense Initiative] speech, in which he called on the nation's scientists to create an impenetrable defense against enemy missiles.

No shield now exists. The nation is naked. Soviet bombs can drop unimpeded on Milwaukee or Washington or any of the 1,000 or so missile silos scattered across the nation's heartland. There is no way to stop an enemy warhead as it speeds toward its target.

The young inventors of Livermore are attempting to change all that. They would have their weapons fire radiation over thousands of miles of space at the speed of light to destroy hundreds of enemy missiles. As the bomb at the core of an X-ray battle station exploded, multiple beams would flash out to strike multiple targets before the entire system consumed itself in a ball of nuclear fire. That is the vision. But the young scientists say their creations will actually bring about an era of unprecedented peace, because the world will know that the threat of nuclear attack from space has forever been laid to rest. The government's overall SDI program is evaluating not only nuclear-powered devices but also conventional lasers, particle beams and kinetic-energy weapons.

The young scientists of Livermore want to use third-generation nuclear weapons mainly against enemy missiles in their so-called boost phase, the best and most challenging point to try to destroy them. A shield must also stop objects that slip through this first line of defense, destroying warheads in the mid-course and terminal phases of the flight. In all, the five-year plan to investigate the feasibility of Star Wars is slated to receive $26 billion. If that money materializes, it will make Star Wars one of the biggest programs of research in the history of Western civilization, an effort rivaling the Manhattan Project and the Apollo moon program.

My first days at Lawrence Livermore were spent among the young warriors, the dozen scientists and graduate students who make up the core of O group, which was the spark plug behind many of the third-generation weapons ideas. Now, toward the end of the week, I was eager to talk with Tom Weaver, the head of the R program, which was charged with turning O group's bright ideas into powerful weapons.

Tom, 34, was a tall redhead with a bushy beard. A high bureaucrat, he nonetheless dressed informally—open collar, casual slacks.

He had gone to Caltech on a National Merit Scholarship. By the time he graduated in 1971, with honors in physics, he had already been interviewed by Lawrence Livermore. That fall he started graduate work at the University of California, Berkeley, financing his graduate education with a Hertz fellowship—founded by John Hertz of Yellow Cab and Hertz Rent A Car renown and supporting some 120 graduate students every year with assets of about $14 million—and commuting back and forth to the weapons lab.

It was not clear to me just how far work had actually progressed on third-generation weapons other than the X-ray laser. Every so often I heard rumors that R program had conducted another test in Nevada, such as event "Romano" in December 1983. Was this an X-ray laser or something more exotic? I suspected that the other weapons ideas were "paper designs" at this point. But I had no way of knowing. Moreover, the public's limited knowledge of what went on at the Nevada test site was getting even more limited under the Reagan Administration. In 1983 it reversed a long-standing government policy of

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GOLDMAN

THE BUTTON

Why the United States may strike out if it tries to strike back.

BY DANIEL FORD

The President's most frustrating problem in preparing to command U.S. forces during a nuclear war is that he may be among the first to die. On an average workday, the President, the Vice-President, the members of the Joint Chiefs of Staff and other top officials will be in Washington. On a few well-known occasions, such as the State of the Union Message, most of them will be in the same room. The priority attached to striking such a central target is a result of the simple logic that it is usually a lot easier for an enemy to bring about disarray by eliminating the other side's leadership than by trying to destroy its entire war machine. Judging from Soviet writings about how to attack the United States, they, too, subscribe to this logic. So, there is no guaranteed grace period for hot-line consultations while intercontinental ballistic missiles (ICBMs) approach each other's territory at speeds in excess of 15,000 miles per hour. In an actual U.S.-Soviet confrontation, the good sense of leaders on both sides could be overwhelmed by the brute fact that they might have little warning time or opportunity to deliberate, a situation made all the more acute by the vulnerability of the leaders themselves to each other's nuclear weapons. Common sense demands deliberation and restraint, but the arrangements now in place for assuring retaliation depend on the ability to take speedy action at the first sign—or apparent sign—of an enemy attack.

In the United States that first sign (assuming that the President survives long enough to get it) may come from the headquarters of the North American Aerospace Defense Command, or NORAD. The installation is buried in the granite of Colorado's Cheyenne Mountain, not far from Pikes Peak and the city of Colorado Springs. It is jointly staffed by personnel of the U.S. and Royal Canadian air forces, and their central mission is to determine whether the Soviet Union has launched a missile or bomber attack against North America. The NORAD Cheyenne Mountain Complex is the front end, so to speak, of the entire strategic command and control system: The warning it provides triggers the back end of the system, which is set up to execute various preplanned retaliatory strikes.

The apex of the decision-making process at NORAD is its Commander-in-Chief. His place during an emergency would be in the main Command Post, the famous room with the wailing alarm Klaxons and giant display screens that has been depicted in nuclear-war movies. When I visited the Command Post, it was hushed, staffed by only a handful of officers, its lighting dim and tinged by the greenish glow from the computer display screens. The battle station, on the balcony at the back of the Command Post overlooking the entire room, was unoccupied at the time, but during a missile alert, the commander would go there to make his "attack assessment," the formal determination of whether the country is under attack.

There are five telephones next to the NORAD commander's battle-station desk. Brigadier General Paul Wagoner, who is in charge of NORAD combat operations and the day-to-day management of the Cheyenne Mountain Complex and who was showing me around, stood behind the desk and explained the function of each one. A black

ILLUSTRATION BY BART GOLDMAN

Author Daniel Ford is featured in Contributors on page 6. From THE BUTTON, by Daniel Ford. *Copyright © 1985 by Daniel Ford. Reprinted by permission of Simon & Schuster, Inc.*

PHOTOGRAPH BY JEFF SMITH

NORAD'S MOUNTAIN REDOUBT

This is Cheyenne Mountain, a forbidding mass of granite looming nearly two miles high at the southern end of the front range of the Rocky Mountains, near Pikes Peak and the city of Colorado Springs. At 8,400 feet above sea level, it is but another peak in the spine of the Continental Divide. However, its presence is felt from the corridors of the Pentagon to the farthest reaches of the Kremlin. Cheyenne Mountain harbors the underground headquarters of NORAD (the North American Aerospace Defense Command), a binational U.S.-Canadian organization. Its mission: to determine whether the Soviet Union has launched a missile or bomber attack against North America. From a cavern that was created by almost a million pounds of explosives blasting out nearly 700,000 tons of granite, NORAD commands a network of early-warning radars, satellites and other sensors.

Those manning the monitors don't stare at empty screens. In 1983, there were more than 500 missile and space launches, and more than 200 were identified as activity in the Soviet Union.

Guarding the entrance, about a third of a mile into the center of the mountain, are two 25-ton, solid steel blast doors, each more than three feet thick, which will close hydraulically in only 30 seconds to seal the complex off from the world outside. Inside, 1,200 to 1,400 feet below the peak of the mountain, are 15 steel buildings. They rest on half-ton steel springs designed to dampen the shock and vibration of a nuclear blast.

Imposing as the solidity it projects may be, the Cheyenne Mountain Complex is not designed to withstand a high-powered explosive. Its life expectancy in a major nuclear war might be no longer than the flight time of a Soviet missile. ■

What about the failed call to the Pentagon? "I didn't know that I had to dial 0 to get the operator."

phone, labeled Secure, provides a direct link between the NORAD Command Post and the National Military Command Center in the Pentagon, he said. Should the commander believe that a Soviet attack may be taking place, the Pentagon is supposed to set up a conference call on that line immediately. The participants in the discussion would include, among others, the Commander in Chief of the Strategic Air Command, the Chairman of the Joint Chiefs of Staff, the Secretary of Defense and the President.

With the black conferencing phone to one ear, General Wagoner said, the NORAD commander would be holding a beige phone to his other ear so he could talk with the NORAD Missile Warning Center, which is in another of the buildings inside the mountain. General Wagoner added that if the commander had another hand, he'd probably want to be holding a red phone that was also on the console. It is connected to a NORAD intelligence center that receives data from the reconnaissance satellites operated by the Central Intelligence Agency and the National Security Agency, as well as information from other United States intelligence sources. A fourth phone was a hookup with the Joint Chiefs of Staff, and the fifth phone was there "in case his wife wants to tell him to bring home a loaf of bread."

A fact sheet that NORAD gives to reporters says, "When we pick up a telephone, we expect to talk to someone at the other end—right now." It occurred to me to ask General Wagoner to demonstrate this, starting with the special black phone that would be used to talk to the President. He picked up the phone briskly and punched the button next to it, which lit up right away. I looked at my watch and waited. He waited too. About 20 seconds elapsed and nothing happened. The general, who seemed somewhat flustered, hung up, mumbled something about perhaps needing "a special operator" and started to talk about other features of the Command Post. I interrupted and pointed to the phone General Wagoner had said was a direct line to the Joint Chiefs of Staff. He picked it up, a bit less confidently than before. Once again, nothing happened. A communications officer then said to the general that the second phone was a "one-way, receive-only" link. I looked at the other three phones, but General Wagoner decided to terminate his testing of the communications system.

NORAD replied to my subsequent written question about the trouble with the black phone to the National Military Command Center by saying that it was also "strictly for incoming NMCC calls." That is incorrect. I spoke to General Wagoner again, and he explained what had gone wrong. "The black phone was an outgoing phone," he said. "I just flat screwed up." At the time, he had been in charge of NORAD combat operations for only a few months, he continued, and was not completely familiar with the communications procedures. He was embarrassed that he had given me a "dumb, dumb demonstration" of NORAD's communications capabilities. There is a high level of redundancy, he emphasized, with several alternate means of transmitting vital messages always available—radio, microwave, satellite or other telephone hookups. When I pressed for information on the specific problem with the call he had placed to the Pentagon, he said, "I didn't know that I had to dial O to get the operator."

The installation of multiple communications systems at NORAD is undeniable. Still, there will be precious little time to search for a working backup once Soviet missiles have been launched—perhaps just a few minutes. Moreover, according to several recent Pentagon studies, it may be very hard to find *any* working communications circuits once Soviet bombs have begun to fall on U.S. soil. This will be an especially severe problem if—as seems likely to the Pentagon—the key U.S. military command posts and message-relay stations are the highest priority targets of a major Soviet attack. In that case, the President will be put in the difficult position of having to make an extremely fast decision on whether the attack that appears on NORAD computer screens is real and, if he thinks it is, whether to order the launching of U.S. Minuteman missiles and other nuclear forces in retaliation. Neither the White House nor the communications lines it depends on are likely to survive the initial phase of a shrewdly planned Soviet first strike, and if the President does not give the orders quickly, he may not be able to give them at all.

The President and his advisers are likely to be quite confused about the various courses of action available to them after a Soviet attack—a problem that is worsened, not mitigated, by the famous black briefcase, the so-called Football, that is carried by the President's military aide. The Football contains authentication codes to order the launching of nuclear missiles. It also contains a notebook whose heavily laminated pages outline the various options in the U.S. nuclear war plan—the Single Integrated Operational Plan, or SIOP, as it is called. Officials familiar with it say that the 75 pages in "the black book" present the President with an extremely complex and virtually incomprehensible set

The Command Post of NORAD, buried deep in the granite of Colorado's Cheyenne Mountain, has one fundamental mission: to determine whether the Soviet Union has launched a missile or bomber attack on U.S. targets.

The President does not have at his beck and call the expertise to deal with problems in a nuclear conflict.

of choices. A senior officer who had worked on the option book said, "No one who had not done an enormously thorough study of it and refreshed himself periodically could possibly understand what he was doing." Bill Gulley, the former Director of the White House Military Office, which safeguards the Football, noted that there is "a kind of mythology" that suggests that it is an "ever-ready Answer Box" that tells the President what to do. "The truth is," Gulley said, "that it raises as many questions as it answers. No new President in my time ever had more than one briefing on the contents of the Football, and that was before each one took office, when it was one briefing among dozens. Not one President, to my knowledge, and I know because it was in my care, ever got an update on the contents of the Football, although material in it is changed constantly. Not one President could open the Football—only the warrant officers, the military aides and the director of the Military Office have the combination."

The President's potential difficulties in overseeing the execution of the U.S. war plan were candidly discussed at a 1981 conference at the Massachusetts headquarters of the MITRE Corporation, a Pentagon consultant. One of the speakers was retired Lieutenant General Brent Scowcroft, the former White House National Security Adviser who headed President Reagan's Commission on Strategic Forces. Some of his observations were "too hot" to be included in the published transcript of the conference, one of the attendees said, but his talk, as it happened, was recorded on videotape. In remarks omitted from the official minutes, General Scowcroft commented, "The President is a very powerful, in some sense, but a very lonely man. He is, perhaps, more isolated than any other senior official in Washington. With the exception of his relatively small NSC [National Security Council] staff, he does not have at his beck and call, at his physical beck and call, the expertise to deal with the problems he would have to deal with in a strategic nuclear conflict."

PHOTOGRAPH BY JEFF SMITH

Pentagon studies that examine deficiencies in the command and control system have focused on particular scenarios that could be exploited in a Soviet attempt to decapitate it. Timing is obviously critical. The Soviets would want to give U.S. leaders minimal warning, lest they issue retaliatory orders while their power to do so remained intact. Since Soviet land-based missiles have a flight time to the continental United States of about half an hour, "it is generally presumed," according to one analyst who has studied the issue at length, "that any Soviet attack against soft command, control and communications centers would involve the use of submarine-launched missiles, in which warning time would be minimal."

At the moment, the main U.S. hope for preserving centralized control after a Soviet attack hinges on the Strategic Air Command's Airborne Command Post, code-named Looking Glass.

Every eight hours, an EC-135 takes off from Offutt Air Force Base in Nebraska or from Ellsworth Air Force Base in South Dakota on a top-secret Looking Glass mission. The specially modified Boeing 707 carries a United States Air Force general, a battle staff, flight officers and communications technicians. They relieve a similar 20-member crew in another plane that has been flying in an undisclosed pattern above the Midwest and that will land after its replacement is in the air. If the Soviet Union were to launch a surprise attack on the United States, the general riding in Looking Glass would probably become the doomsday officer responsible for giving the U.S. missile and bomber forces the order to retaliate.

SAC will not officially acknowledge the investiture of the Looking Glass commander as a potential surrogate for the President, but it does acknowledge that the plane is "the first place command goes" if SAC headquarters at Offutt is destroyed. Officials also state that Looking Glass has all of the means to "build, process and disseminate an Emergency Action Message"—the coded orders that direct the missile and bomber forces to execute the SIOP, the nuclear-war plan—and that it "has the authentication codes required to do that." The essential documents are kept in a double-locked, fire-engine-red "clacker box"—so named because of the sound of the alarm that goes off when this steel safe is opened. The general in command and the chief of the airborne battle staff hold the keys.

Under actual combat conditions, the situation would be more tense. Having been on board one of the standby

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VICTORY AT SEA?

THE NEXT GREAT GLOBAL CONFLICT MAY INVOLVE TESTS OF NAVAL POWER.

BY T. A. HEPPENHEIMER

For the third time in a century, the world is at war. It is a few years prior to the year 2000. The aircraft carriers *Abraham Lincoln*, *Theodore Roosevelt* and *John F. Kennedy*, supported by powerful naval escorts, speed at 30 knots as they sail north of Norway's Lofoten Islands. The mission is to launch an attack on the Soviets' bomber bases on the Barents Sea. It will draw out Soviet air and sea forces in major counteratttacks, the United States and its NATO allies are gambling that they are strong enough to destroy them. It is a classic instance of the boast of John Paul Jones, "I intend to go in harm's way."

On the decks of the carriers, F-14 and F-18 aircraft stand armed and ready. Overhead, an E-2 early-warning aircraft with its huge rotating radome watches for an attack. They do not have long to wait. Out of the east, the radar operators pick up first a formation of Soviet Backfire bombers, then a squadron of Blackjack bombers (the Blackjack will go into service in 1987), nearly 50 planes. Each has two cruise missiles. Within seconds, the carriers launch their aircraft.

At speeds well above Mach 2, the F-14s fly to battle, each one armed with a variety of air-to-air missiles as well as a rapid-fire 20-mm cannon for fighting at close quarters. From distances up to 100 miles, the pilots pick out enemy bombers and, using their radar fire-control systems, launch up to six Phoenix missiles at once, each against a different target. The sky fills with streamers of smoke as Soviet bombers begin to fall. The Yanks listen for a growling tone in their head-

A formation of 16 of her 90 planes takes off from the flight deck of the U.S.S. Nimitz. This 81,000-ton carrier is also fitted with three Phalanx guns and the Mach 1 ship-to-air Sea Sparrow missile.

phones, the signal that their close-range Sidewinder missiles have locked onto a target. Still the surviving Soviets keep coming. Some 150 miles from the center of the battle group, they begin to launch their missiles. As the last of them fall away, the two air forces break off and turn for their bases. Rockets, not aircraft, will fly to defend the fleet. As the first cruise missiles come within 30 miles of the outlying destroyers and light cruisers, the computer-controlled Aegis combat system tracks them, then replies with auto-piloted SM-2 missiles. Each ship will keep no less than 18 of them in the air at a time.

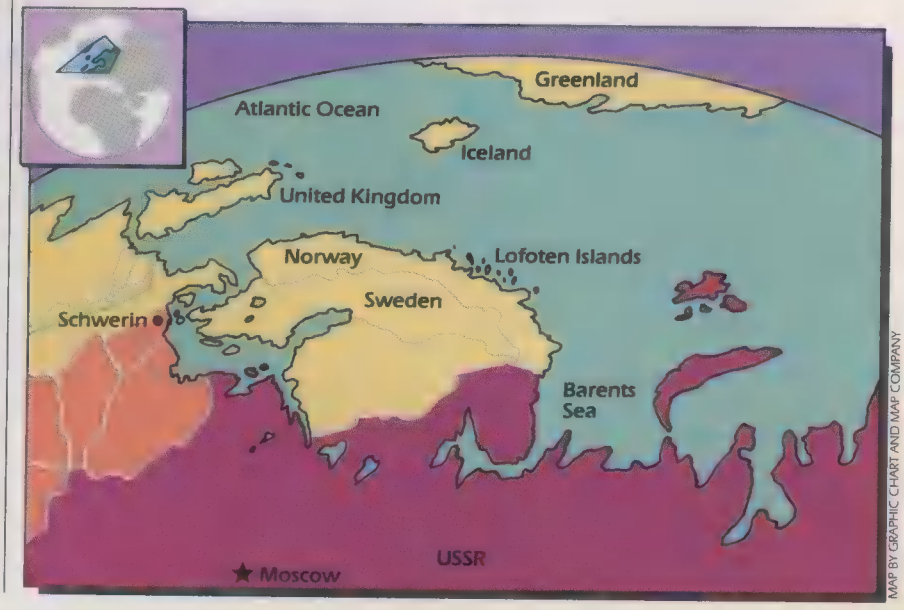
The surviving cruise missiles continue to fly through a screen of electronic countermeasures coming from the destroyers and cruisers. Some ships turn on their radar transponders to echo back a delayed and amplified return to the tracking radars in the cruise missiles' guidance systems. The delays of a microsecond or two lead to a misreading of the ships' locations. The amplifications register the small destroyers as carriers. Other transponders return particularly strong radar signals, blinding the missiles as if shining a bright light in a person's face. Some ships spew out clouds of chaff, metallic foil, to produce the appearance of other large targets. As the missiles zero in, they are met by the rapid fire of automatic machine guns firing 6,000 rounds per minute. The gun, called Phalanx, is radar-guided and tracks both an incoming missile and the stream of bullets, then adjusts the aim to make a hit.

In the end, only three Soviet missiles find targets. One leaves a destroyer burning and dead in the water; a second blows a gaping hole in the side of a light cruiser. The third, confused by countermeasures, misses the vital bridge of the carrier *Roosevelt* and hits close to the stern. A blazing fireball buckles deck plates, enveloping crewmen in flame. The tally for that morning shows 30 Backfire and Blackjack bombers lost. The U.S. losses are the destroyer, the cruiser

The author traveled the country talking to the naval experts who build war scenarios.

In addition to its nine powerful 16-inch guns, the recommissioned battleship New Jersey is equipped with a variety of long-range, state-of-the-art missiles.

Europe, seen from near Moscow: A U.S. battle group will steam north of the Lofoten Islands to attack Soviet bomber bases near the Barents Sea. It is anticipated that Soviet air and naval forces will give battle, but that U.S. ships and planes will punish them severely.



MAP BY GRAPHIC CHART AND MAP COMPANY

and more than a dozen flight-deck crewmen.

This scenario is not a clip from a Hollywood movie. Rather, it reflects the views of an increasing number of military leaders and analysts, who visualize a dramatic turn in Soviet strategy should a war develop. While public attention has focused on the buildup of nuclear-tipped missiles, many military analysts have become convinced that should the Soviets be drawn into warfare they would plan to fight a lengthy and widespread conventional war, one that would involve no nuclear weapons. Rather, warfare would involve massive firepower on a variety of fighting fronts. In such a war, as in World Wars I and II, control of the sea could be one of the keys to victory.

What of the widespread view that war between the superpowers must inevitably lead to nuclear weapons? Twenty years ago, that view may have been correct. During the post-Khrushchev years, however, the Soviet leaders have moved away from a position of nuclear aggression. Marshal Dimitri Ustinov, the late Minister of Defense, stated in *Pravda:* "Only extraordinary circumstances—direct nuclear aggression against the Soviet Union or its allies—could compel us to resort to a retaliatory nuclear strike."

This does not mean that the Soviets have decided to disarm. Rather, in the view of James McConnell of the Center for Naval Analyses, a leading expert on Soviet strategy, "they do not think it will be necessary" to use nuclear weapons. McConnell has pointed to Soviet confidence in its ability to fight and win a conventional war, noting that "there are extensive propaganda benefits to be derived from publicly foisting off on an opponent the odium of escalating the costs of war."

Analysts believe the Soviets plan to fight a lengthy conventional war.

What is more, Soviet leaders have not been shy about stating the sort of war they are prepared to fight. Marshal Nikolai Ogarkov, until recently Chief of the General Staff, has written that such a war "could encompass Europe, the Near, Middle and Far East, and all sea and ocean theaters." Other Soviet leaders have declared that the war could be a world war "extending over many years" and that as many countries could get involved in it as there were in World War II.

In the opinion of some analysts, the Soviet shift toward conventional war implies the prospect of a war at sea. Ten years ago, their navy was already a formidable force, with ballistic missiles carried in nuclear subs. Yet in the Soviet military journals, the entire navy was seen as having no more than a "significant" or "serious" effect on the outcome of a war between the superpowers. The "decisive" or "main" blow would come from their Strategic Missile Troops, armed with ICBMs. In 1982, however, Marshal Ogarkov stated that these forces could have only a "substantial" influence. Since then, the principal Soviet naval journal, *Morskoy Sbornik* (*Naval Digest*), has carried a flurry of articles on war against the sea-lanes linking the United States and Europe. According to these articles, such attacks could have a "most important" effect on any conceivable war in Europe.

This does not mean that such a war is imminent. At the Hudson Institute, Frank Armbruster, a longtime associate of the late strategist Herman Kahn, has developed scenarios for the outbreak of a conventional war in Europe. "In my judgment," he states, "it is extremely difficult to write a scenario that leads to a general war in Europe." Nevertheless, he has shown how such a war could break out.

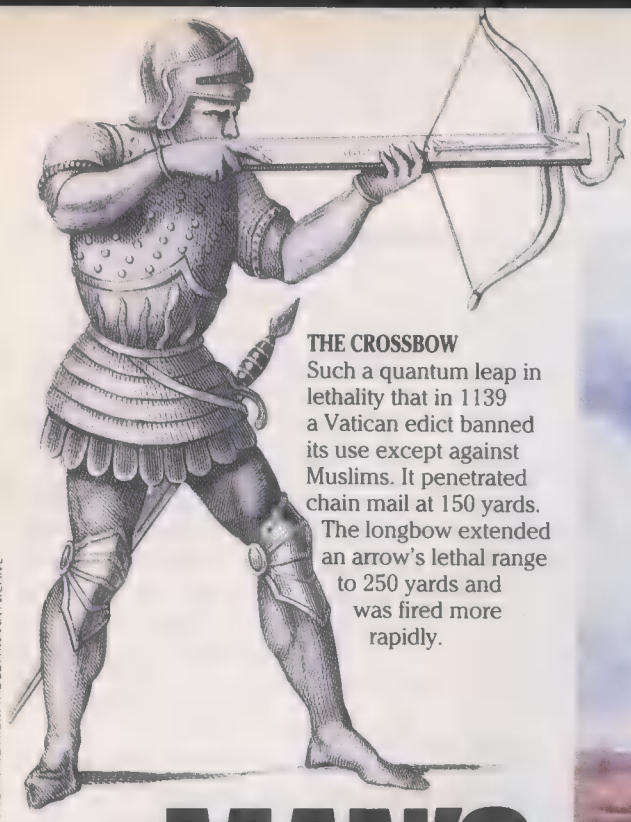
Armbruster's scenarios are established in Germany. In one of them, a workers' strike in Schwerin, East Germany, builds into a local revolt, close to the border. It is November and the widespread rain has commanders edgy. The East Germans and then the

Continued on page 80

SEA POWER

Although the U.S. edge in carriers is clear, many Soviet ships, including submarines, carry cruise missiles that would put them at risk.

US		USSR
15	Carriers and Battleships	5
98	Subs	369
191	Other Combat Ships	288
2,140	Combat Aircraft	885



ENGRAVING FROM THE BETTMANN ARCHIVE

THE CROSSBOW
Such a quantum leap in lethality that in 1139 a Vatican edict banned its use except against Muslims. It penetrated chain mail at 150 yards. The longbow extended an arrow's lethal range to 250 yards and was fired more rapidly.

MAN'S DEADLY QUEST

The Search for the Ultimate Weapon

BY TOM GERVASI

ARTILLERY
By 1500, siege cannon, left, had rendered formal fortifications obsolete. But mobile, horse-drawn artillery remained master of the battlefield. In 1815 at Waterloo, above, 50 percent of the Allied casualties were caused by Napoleon's cannon.

ENGRAVING FROM CULVER PICTURES

PAINTING FROM THE GRANGER COLLECTION

The most successful form of socially organized killing inflicted by man upon man is war. Its primary justification has been self-defense. Yet this has seldom been its cause. Nations have promised to use weapons only to defend themselves but have used them to attack one another instead. As often as they have attacked out of genuine fear, they have contrived fear. As often as they have sought to protect their security, they have sought to protect wider interests. Since World War II, an experience no participant has wanted to repeat, most of the world's War Ministries have been renamed Ministries of Defense. This merely reflects our contrary impulse to find killing unacceptable, to excuse it only if it is unavoidable and to rationalize our unending search for the ultimate weapon. The more quickly a war can be concluded, it is argued, the fewer the casualties.

Technology has played a pivotal role in our search for the ultimate weapon. We have seldom failed to appreciate its possible applications to war. According to one estimate, 40 percent of the physicists and engineers in the United States are engaged in military research and development.

Until the dawn of the nuclear age, every weapon that promised to be an ultimate weapon turned out not to be.

The horse was thought to be the first. At the watershed battle of Adrianople in A.D. 378, the Roman legions, which had been supreme in their days of glory, were confronted with the cavalry of the Visigoths and Ostrogoths. The legions left 40,000 dead on the field, including the emperor, Valens. Massed infantry had given way

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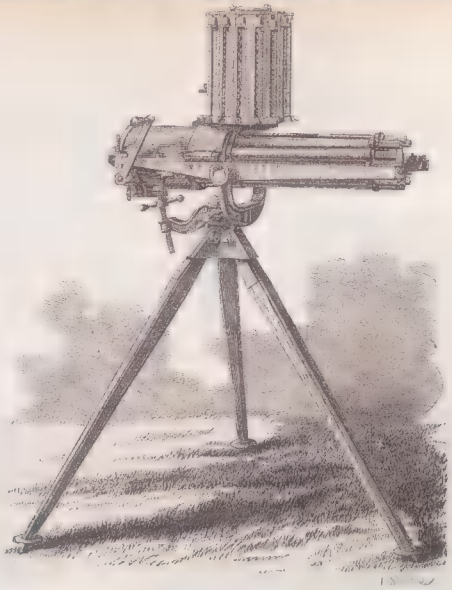
Tom Gervasi, who is the author of Arsenal of Democracy, *appears on the Contributors page.*

LITHOGRAPH FROM THE GRANGER COLLECTION

BATTLESHIPS
Monitor, left, blocks the *Merrimack*'s way out of a Union blockade in 1862. In 1921, Billy Mitchell would bomb and sink a captured German battleship, proving that armored ships were vulnerable to far more than other dreadnoughts.

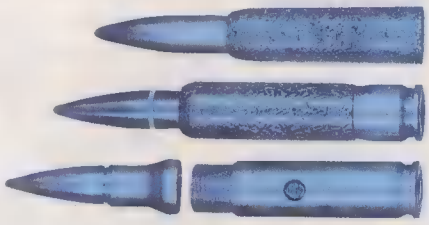
MAN'S
DEADLY QUEST

The casualties have only



ENGRAVING FROM THE BETTMANN ARCHIVE. PHOTOGRAPH FROM THE PICATINNY ARSENAL, COURTESY TOM GERVASI

THE GATLING GUN
An American invention that was first used in 1866, it could fire as many as 600 rounds per minute. Similar guns were largely responsible for the 11,000 Mahdist dead left on the battlefield at Omdurman, in the Sudan, in 1898.



CONOIDAL BULLET
When the musket ball was reshaped with a conical point, it soon replaced artillery as the primary cause of death in combat. It was responsible for 86 percent of our Civil War casualties. Cannon caused only 9 percent.

to the man on horseback.

Cavalry would dominate the battlefield for centuries; bows and arrows made the horsemen a lethal weapons system. With them, an army of Genghis Khan's Mongols rode to destroy the Russians at the battle of the Kalka River in 1223. Armies stepped back from hand-to-hand combat, placed some distance between themselves and began to learn how to launch lethal projectiles of various kinds more effectively.

Since that time, the goals of military invention have remained unchanged. Projectiles were thrown, loosed from bows and eventually fired from the barrels of guns. We have sought to increase their speed, in order to extend their range and increase their impact, as well as to shorten the time they take to get to their targets. We have sought to improve their accuracy and to increase their density at the point of impact, either by launching them in greater

PHOTOGRAPH FROM THE BETTMANN ARCHIVE

AIR POWER
At center, right, General Billy Mitchell, who forecast the major role air power would play in war. He had led 1,481 Allied aircraft, the largest force to that date, during the U.S. attack on the St.-Mihiel salient in 1918.

PHOTOGRAPH FROM UPI/BETTMANN NEWSPHOTOS

increased as weapons have grown more lethal.

numbers, launching them more frequently or breaking them up into pieces at their arrival on target.

The crossbow had more speed and accuracy than the javelin. The longbow increased range. With the invention of gunpowder, the iron ball further increased range. A simple improvement in bullet design, bringing its head to a point, reduced air resistance and increased range even more. The rifling of barrels spun bullets and gave them greater accuracy. The advent of high-quality steel allowed the use of greater propellant pressure without bursting the gun barrels, increasing range still further. Breech-loading cannon increased the rate of fire. The machine gun and the high-explosive fragmentation shell also increased density. Ballistic missiles developed increased explosive power and dramatically reduced the time it took them to reach targets.

PHOTOGRAPH FROM CULVER PICTURES

GAS
An early protective mask. Gas, too, was thought to be the ultimate weapon. But it soon proved, like nuclear weapons, to be an indiscriminate killer, whose use only risked provoking retaliation in kind.

The age of electronics has produced precision guidance. This has increased accuracy to such an extent that it has now become a more significant factor in lethality than explosive power.

We have made parallel efforts to protect ourselves from an opponent's

THE TANK
At Cambrai in 1917, massed British tanks were used for the first time and penetrated six miles into enemy lines. Though tanks have become far more formidable, so have the antitank weapons used against them.

PHOTOGRAPH FROM CULVER PICTURES

ZEPPELINS
Dirigibles like this one promised the first real threat from the air. It did not materialize. Too many drifted off course. They carried little weight in bombs. The *Hindenburg* explosion proved their weakness.

With the dawn of the nuclear age, war

PHOTOGRAPH FROM THE PICATINNY ARSENAL, COURTESY TOM GERVASI

ANTITANK WEAPONRY
The M735 projectile, fired from the 105-mm tank gun, has a muzzle velocity of 5,875 feet per second and can pierce 18 inches of armor.

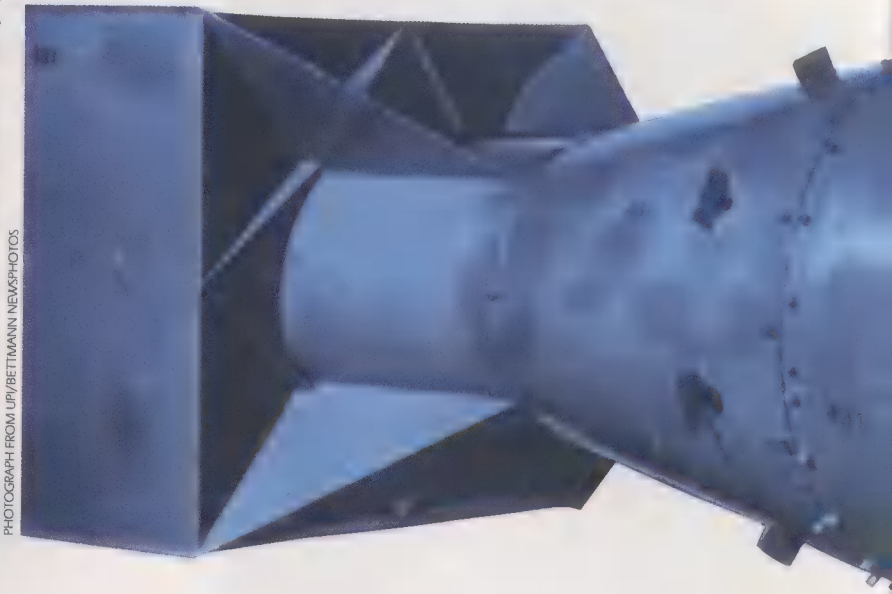
projectiles, first with shields, next with fortifications, then with armor and finally with early-warning systems and dispersion. We have found new positions from which to launch our own projectiles. We have taken to the air, to attack from overhead with guns and bombs. We have brought our guns forward into enemy ranks, protecting them with armor in tanks. We have taken our guns to sea in wooden ships to attack from offshore and then armored our ships to protect them from the guns that others have brought to sea.

Each of these developments inspired a response and precipitated a technological duel that continues to this day. Tanks brought on antitank guns. Thicker armor was used to resist their projectiles. More powerful guns were built to penetrate that armor. Bombers were soon attacked by fighters and antiaircraft guns and missiles. Armored ships, better protected from one another, were attacked by aircraft from above and by submarines from below.

To those who thought they had found the ultimate weapon, it promised the end of war. A prudent adversary, they reasoned, would simply

PHOTOGRAPH FROM AP/WIDE WORLD PHOTOS

BALLISTIC MISSILE
The latest refinement of an evolution that began with rockets used by the British at the bombardment of Boulogne in 1806, the MX missile, left, using mid-course guidance from NAVSTAR satellites, will be able to deliver its warheads to within 300 feet of their aim points.



PHOTOGRAPH FROM UPI/BETTMANN NEWSPHOTOS

PHOTOGRAPH FROM U.S. AIR FORCE

AMERICA'S B-52H
With a range of 8,950 miles, it can carry as many as 24 nuclear weapons. By contrast, most of the largest Soviet bombers, the prop-driven Tu-95A Bears, carry only one nuclear weapon.

between the nuclear powers risked suicide.

REENTRY VEHICLES
An MX missile bus with its nose cone removed, showing the Mark 21 reentry vehicles inside. Each MX will carry 10 of these. Together, they could obliterate Moscow. Singly, each could literally dig out and vaporize any Soviet missile silo, for each would make a crater with a larger radius than its likely margin of error in striking its aim point.

PHOTOGRAPH FROM UPI/BETTMANN NEWSPHOTOS

surrender, not fight. To those who thought they faced the ultimate weapon, it promised the end of the world.

The crossbow, machine gun and poison gas were each thought to be the end of the world. Yet each time, no one behaved as predicted when confronted with them. No one surrendered. Then it was not the end of war. Nor was it ever quite the end of the world. Yet neither were the casualties of war reduced. The casualties have only increased, as weapons have grown steadily more lethal through the ages.

As they watched the first nuclear explosion near Alamogordo in 1945, many scientists and government officials believed that this moment truly signaled the end of war. At last, they believed, the human race must bring an end to its instincts for power and aggression, or those instincts would bring an end to the human race.

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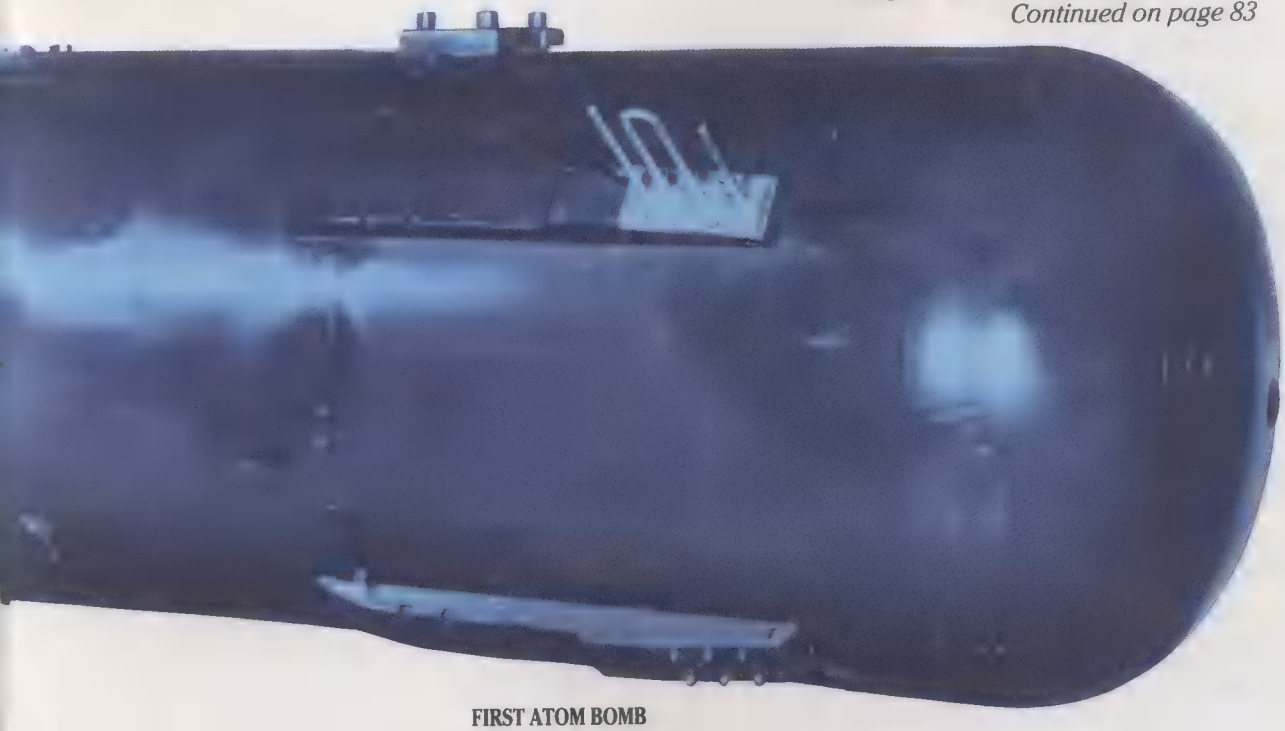

FIRST ATOM BOMB
Little Boy, the type of bomb detonated over Hiroshima in 1945. Its explosive yield was roughly 13 kilotons. By contrast, the yield of each Mark 21 reentry vehicle shown at the top is 300 kilotons.

THE GREAT ARMS BAZAAR

BY TOM YULSMAN/PHOTOGRAPHS BY PETER MENZEL

The Air Show scene: a row of Paris cafés in an armed camp.

Weapons makers gather in the city of light to hawk their latest instruments of warfare.

The nations of the world spent an estimated $967 billion last year on weaponry and armed forces—$203 for every man, woman and child on the planet. Nowhere is that expenditure more dramatically evident than at the Paris Air Show, a 10-day extravaganza held every two years at Le Bourget Airport on the outskirts of the City of Light. This is the thirty-sixth Paris Air Show. Surrounding the overwhelming display of the instruments of war is the tightest security network this biennial bash has seen in two decades. Some 2,000 police and private security personnel (many heavily armed) are guarding against attacks threatened by terrorists.

The Paris Air Show is more than a showcase for airplanes. It is the world's premier arms bazaar. From 33 nations, 1,000 exhibitors have come to display their wares (some of them commercial) and to hustle the latest helicopters, jet fighters, missile launchers, radar-guided antiaircraft guns and armored vehicles. Displayed on the tarmac are missiles of every size and function (including the infamous Exocet), Beech Aircraft's new BQM-126A target drone, capable of operating at speeds up to 666 miles per hour, rapid-fire machine guns, runway-penetration bombs and torpedoes. While munitions executives mill about the displays, fighter aircraft inscribe high-g loops in the sky, their afterburners glowing and thundering in unparalleled displays of power and grace.

At least 200 aircraft are parked in a haphazard array of shapes and sizes, including the Soviet An-124, a wide-body cargo aircraft said to be the world's largest, and General Dynamics' F-16C fighter, among the world's most sophisticated. Grumman is showing off a full-scale mock-up of its forward-swept-wing X-29 (*Science Digest*'s cover, May 1985). Dassault-Breguet has countered with both a flying Mirage 2000 and a full-size mock-up built of transparent plastic. Notable for its absence is Northrop's F-20 Tigershark—a U.S. fighter intended for export that was the first and only ever built without a government contract. The F-20 that was to have flown here crashed during a trial flight in Goose Bay, Labrador, killing its pilot. Northrop decided

Senior writer Tom Yulsman frequently writes about aviation and military technology.

Spain displayed the flexible firepower of the CASA C-101 ground-attack jet: two tons of bombs, missiles and cannon shells.

REMOVE BEFORE FLIGHT
D-HDTV

At the Air Show, no expense is spared to display the free world's military might.

not to fly the remaining prototype to the show.

The major arms makers are here en masse: Aerospatiale, Messerschmitt-Boelkow-Blohm, Raytheon, British Aerospace, Lockheed, Rockwell, Hughes and many others. The festivities and displays cost them several million dollars each. Their executives wine and dine potential customers in plush "chalets" that line the main runway. For the free world, the Air Show is like the November 7 parade (the anniversary of the Bolshevik revolution) in Moscow's Red Square, where the Soviets spare no expense to display their military might. Unlike the USSR, however, the name of the game here is buying and selling.

Manufacturers unabashedly push their products. In the American pavilion, for example, a wall of 13 video monitors promotes a 9-millimeter submachine gun from Viking Systems Inc. With pulsating music, a commercial shows the gun submerged in water, dropped in sand and covered with snow. Like the watch in the old Timex commercial, the gun keeps on ticking. "When there can be no compromise, Viking is the only selection," intones the commercial.

With a diagram of the choreography held in their laps, observers atop the General Dynamics chalet watch the company's F-16C inscribe loops in the sky, its afterburner glowing and thundering during a powerful flight demonstration that was one of the highlights of this year's show.

In the chalet of Lear Siegler (a manufacturer of airplanes and avionics), magician Deane Stern entertains potential clients with dazzling card tricks. "It looks like magic," he says, "but it's not. It's know-how. Man in control. Engineering prestidigitation." Presumably the kind that goes into Lear Siegler products.

The gloss and games, however, are just a sugarcoating over more serious business. The prestige, not to mention the well-being, of corporations and governments—billions of dollars in future sales—are at stake here.

"At the 1975 show," says Al Spivak of General Dynamics, "flight demonstrations showed a graphic difference between our F-16A and the Mirage F-1E." Observers say the Mirage lumbered ponderously down the runway, eating a lot of asphalt before taking off. The F-16A was airborne quickly and shot vertically skyward like a rocket. "On the last day of the show, four European nations announced that they had decided to purchase our F-16s," says Spivak.

This year, the F-16C, an updated version of the F-16A, is competing against Dassault's Mirage 2000. (It was also to have competed against the F-20, but the tragic crash prevented it.) The F-16C is capable of flying at speeds in excess of 460 mph at 200 feet off the ground—even in poor weather conditions and at night. An infrared image of the terrain can be projected on the pilot's head-up display (HUD), a transparent screen mounted at eye level. Targeting symbols are superimposed, indicating release points for bombs. The first F-16C Fighting Falcons were delivered to the Air Force last year. Turkey, Greece, Israel and Egypt have agreed to purchase the plane, and other sales are expected. General Dynamics puts the "flyaway cost" at $13 million a plane. A budget request before Congress, however, estimates the cost to be between $18 and $20 million.

The F-16C delivers an impressive

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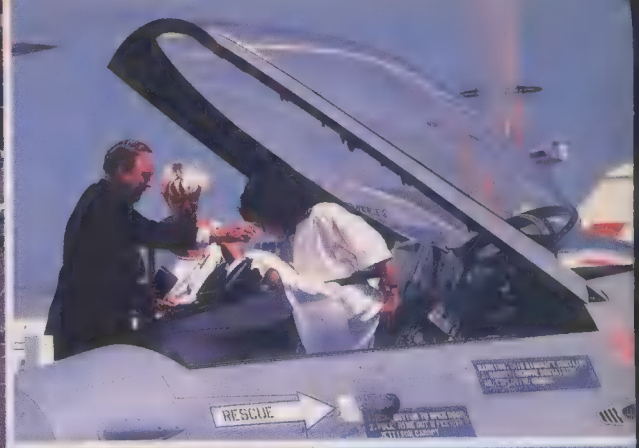
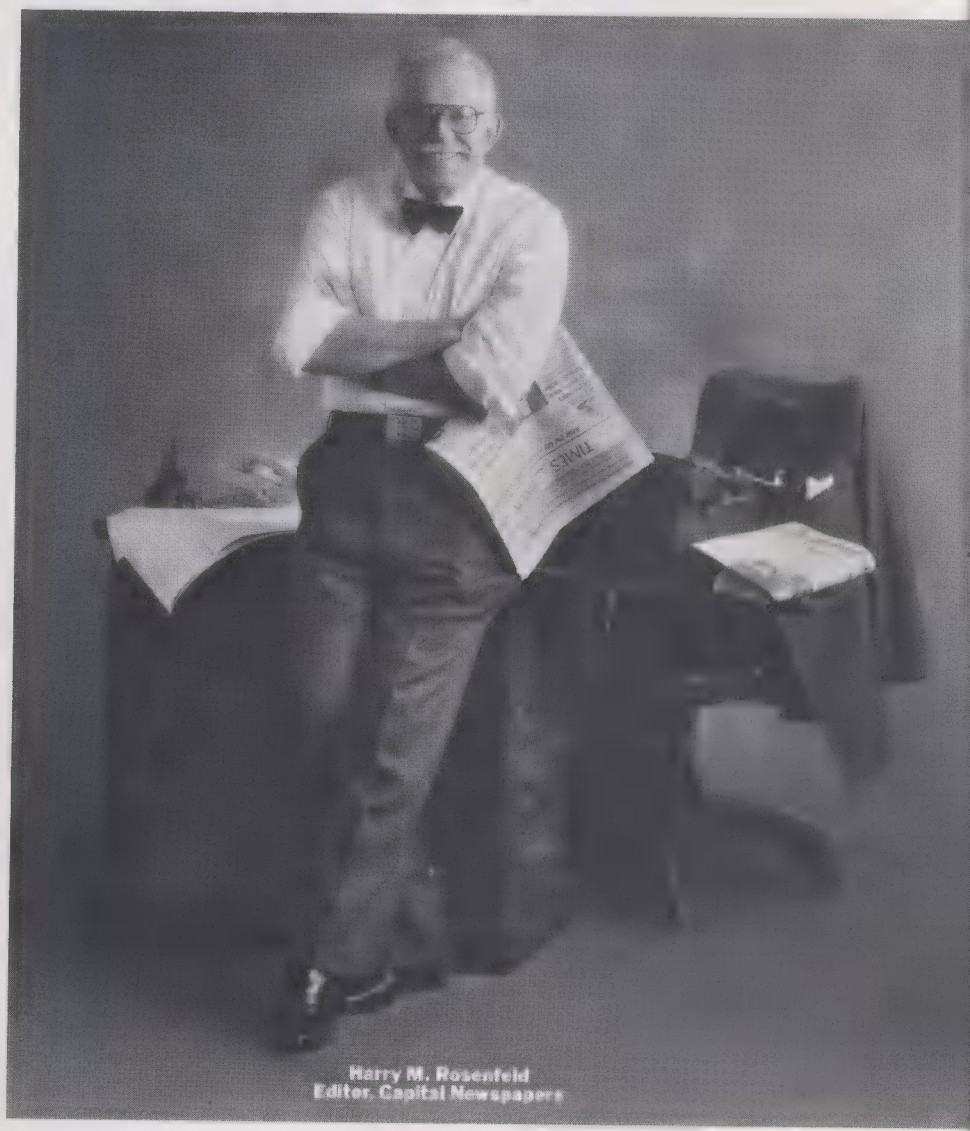


Clockwise from top left: 200 aircraft, and myriad missile launchers, radars, bombs and cannon, were on display at the Paris Air Show, seen here in an aerial view. General Dynamics opened the canopy of its supersonic F-16 fighter to let visitors glimpse its sophisticated avionics. Children and parents gaped at the weaponry, including Raytheon radar-guided ground-to-air missile systems. Inside "chalets" set up for the occasion, executives and buyers feasted on haute cuisine. Meanwhile, sales discussions continued outside by the hardware, such as Sikorsky's H-76 attack and combat-support helicopter, which holds 12 world records for speed, altitude and rate of climb. Antiwar demonstrators were quickly dispatched. And while Air Show participants appraised the products, such as the Italian AMX light attack fighter and Thomson-Brandt armaments, mainland Chinese were as inscrutable as ever as they viewed capitalist arms.

Harry Rosenfeld had the creative ideas that have made Hearst's Albany newspapers 'must reading' in New York's state capital.



Harry M. Rosenfeld
Editor, Capital Newspapers

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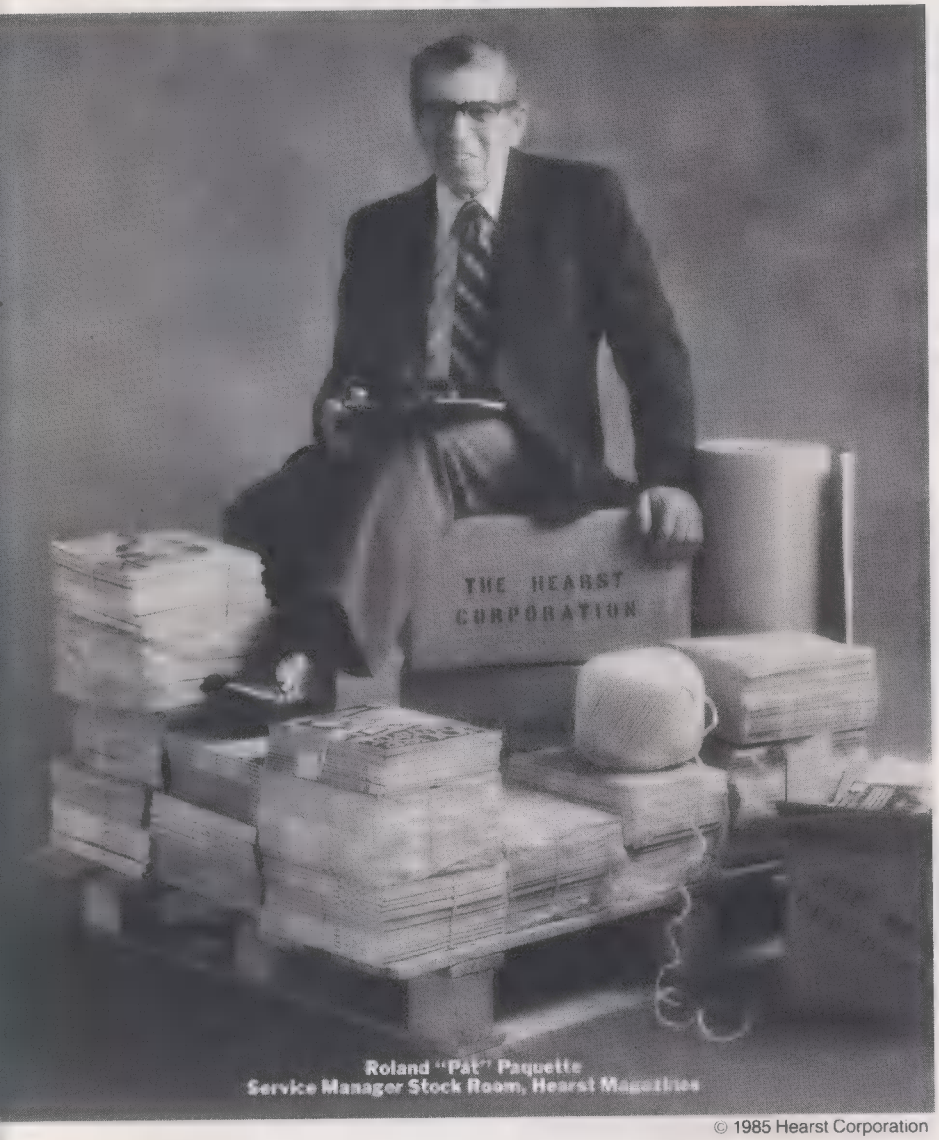
Pat Paquette's creative ideas at The Hearst Magazines Division started 53 years ago and haven't stopped yet.



Roland "Pat" Paquette
Service Manager Stock Room, Hearst Magazines

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THE PROMISE OF ARTIFICIAL SKIN

We take our living space suit for granted—until it is burned beyond repair. Now science offers hope.

BY DAVID HELLERSTEIN

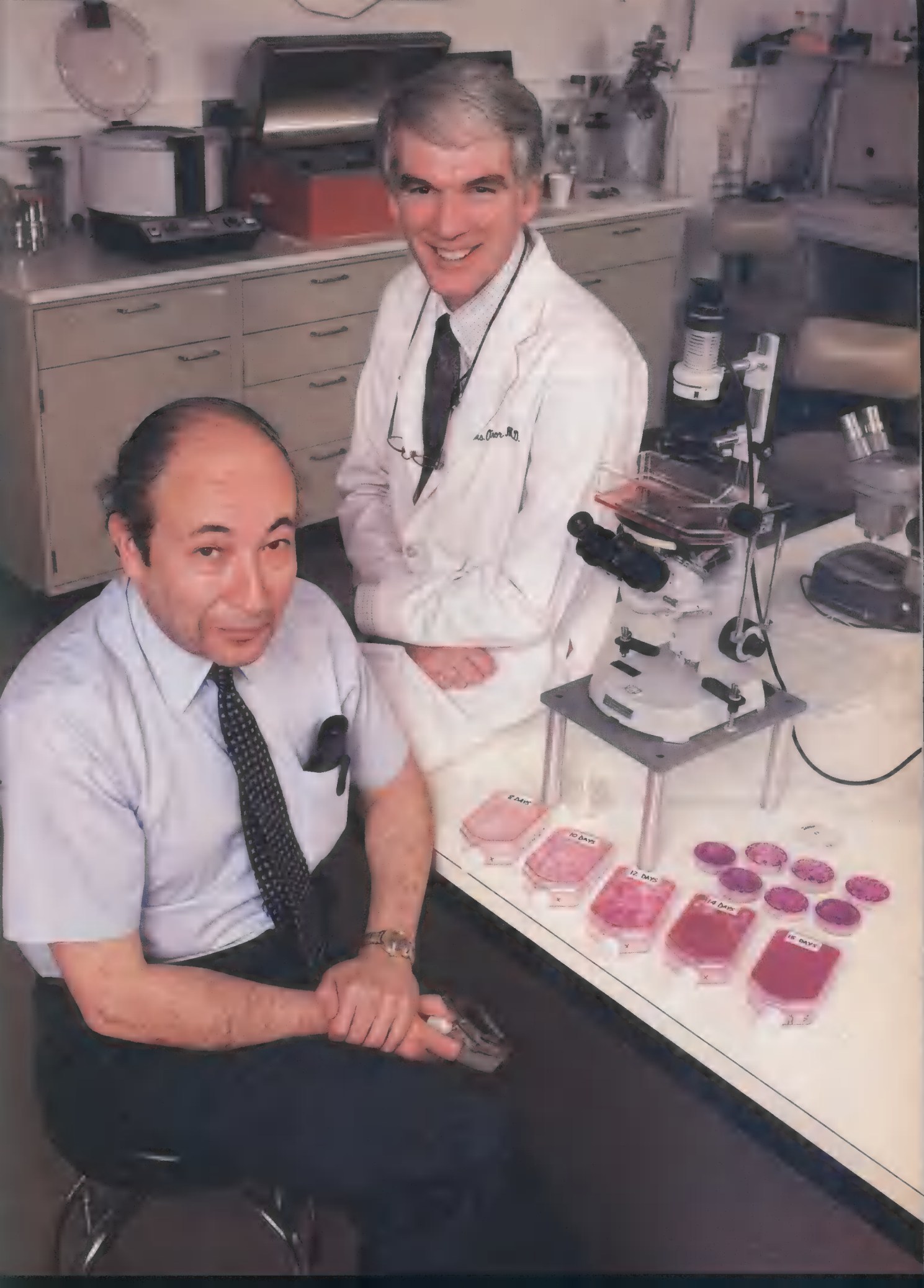
To really understand the importance of skin, you have to know what life is like for people who don't have enough of it—the burned. It's no accident that the Puritans consigned the worst of their sinners to roast in the fires of Hell, or that the most terrifying of medieval tortures was to be burned alive—there's no suffering to compare with that of the burn victim. Not only because skin is the vehicle of touch and sensation, of pleasure and pain, the repository of a half dozen different types of sensory receptors, pressure-sensitive capsules and heat-sensitive bulbs, and naked nerve endings that respond to pain and temperature—but also because skin is a living space suit, regulating temperature and fluid balance, protecting against mechanical injury and infection. In its absence, all these systems run amok.

And so, a burn unit—any burn unit—must be the closest thing there is to Hell on Earth. During residency training, I worked for six months as a psychiatric consultant on a burn unit, and I still tremble at the thought of burn patients' suffering. Not only were they invaded by infection, liable to severe dehydration, at risk at any time of going into shock, and suffering severe pain, but the treatment they received—the best medicine has to offer—was often as painful as their condition. Especially for patients with extensive third-degree burns—burns so deep that the skin cannot regenerate from lower layers, as it can with less severe burns—their suffering was astonishing and horrible. Once their burns were cleaned, one of a variety of temporary coverings would be laid over them—pigskin, human cadaver skin, petroleum-jelly gauze, various artificial membranes. Then, days to weeks later, the terrible ordeal of grafting would begin. Skin would be removed in a sheet from an unburned part of the body and applied to the burned area, where, if there wasn't too much infection, it would begin to grow. Often, before the burn area was completely covered, several waves of grafts would be required, each exquisitely painful at the donor site—the place where grafts were "cropped." And even then, the patient would of-

Psychiatrist and writer David Hellerstein is now a contributing editor to Science Digest.

PHOTOGRAPH BY JILL KREMENTZ

Dr. Howard Green (left), of Harvard Medical School, and Dr. Nicholas O'Connor, of the Shriners Burns Institute, with epithelium cultures.


8 DAYS
10 DAYS
12 DAYS
14 DAYS
16 DAYS

ten have contractures around joints, would have limited motion in various limbs; and there could also be debilitating psychological effects from scarring, since skin grafts, cut into a mesh to increase surface area, frequently heal as heaped-up, angry-looking scars. If more than, say, 50 or 60 percent of the body had been burned, there might not be enough donor areas to harvest; such patients often died.

Before the burn unit, I never thought much about skin. In medical school, we laughed at classmates interested in dermatology—they'd spend their careers popping pimples and removing blackheads while the rest of us treated real disease. And I skimmed over the histology and physiology textbook sections on skin. As much as they talked about skin as an organ, and rhapsodized about its unique properties, it was hard to get too interested in something that just sat there, that didn't beat every second, like the heart, or somehow produce thoughts out of chemicals, like the brain. Skin was just . . . skin. It was like clothing: If it fit well, so much the better; if not, call in a cosmetic surgeon for a few nips and tucks.

But the burn unit sent me scurrying back to the textbooks. Skin is one of the largest organs in the body, they told me, composing about 16 percent of body weight. It protects us from injury, from infection, from ultraviolet light. It can excrete, it receives stimuli from the environment, it plays a role in water balance and the metabolism of vitamin D.

Skin is basically a two-layer membrane. The lower, thick, spongy dermis, one to two millimeters thick, is primarily connective tissue, rich in the protein collagen; it protects and cushions the body and houses hair follicles, nerve endings and sweat glands, blood and lymph vessels. The upper layer, the epidermis, is 0.07 to 0.12 millimeter thick. It is primarily composed of squamous, or scalelike, epithelial cells, which begin their lives round and plump at the boundary of the dermis and over a 15-to-30-day period are pushed upward, toward the surface, by new cells produced below. As they rise, they become flattened, platelike, lifeless ghosts, full of a protein called keratin, and finally they reach the surface, where they are ingloriously sloughed off into oblivion.

The textbooks leave out the wonder of skin in their dry recitations. Not only that skin is an organ of definition and delight, but that it is self-renewing, self-replicating. It assembles itself. The epidermis knows top from bottom, in from out; its cells push in one direction only, constantly surfacing. And all this results from the unique properties of one cell type, the squamous epithelial cell.

Skin is so simple—and the consequences of skin deficiency are so dreadful—that one has to wonder. Shouldn't it be possible to invent an equally simple patch kit, so you could replace what's missing as easily as slapping a new piece of rubber onto a punctured tire? So that even large burn areas could be covered quickly and permanently with new skin?

□

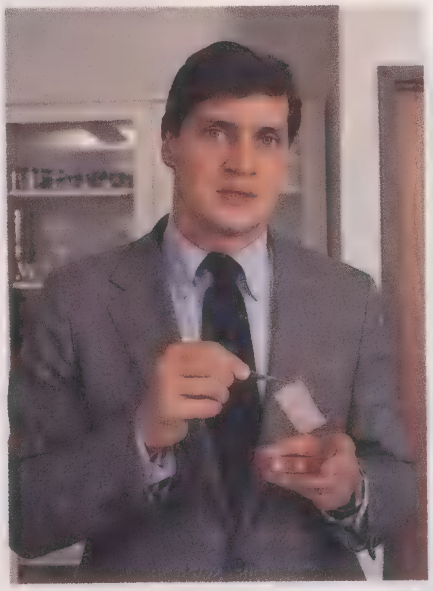
Last year, the beginnings of an answer to this question made news. The *New England Journal of Medicine* published a report of a revolutionary new technique of skin replacement developed by a research team headed by Dr. Howard Green of Harvard Medical School. A year before, two brothers, Jamie and Glen Selby, ages five and six, had been severely burned after solvent they were using to remove paint from their naked bodies had accidentally ignited. Jamie suffered 83 percent and Glen 89 percent third-degree burns; their total burn areas were 97 and 98 percent, respectively.

In a dramatic lifesaving procedure, a surgical team headed by Drs. Nicholas O'Connor and Gregory Gallico III, of Shriners Burns Institute, removed postage-stamp-size pieces of skin from the boys' armpit areas and cultured them in the laboratory into large quantities of epithelium. These were transplanted in several waves of grafts to 49 percent and 54 percent of the boys' bodies. Within 14 months both boys were back home in Wyoming, and one of them had even gone back to school.

What was remarkable about the Selbys' case was not only their survival—unprecedented for such extensive burns—but the fact that the boys were

PHOTOGRAPHS: LEFT BY DAN MCCOY/RAINBOW; RIGHT BY RICK FRIEDMAN/BLACK STAR

This was not some fancy dressing but real skin.



Dr. Gregory Gallico (above), of the Shriners Burns Institute, holds a sheet of epithelial cells attached to gauze.

Dr. Ioannis Yannis of MIT with a sheet of artificial dermis which is ready to be seeded with young epidermal cells.

given a permanent new skin. Their transplants were not merely some fancy wound dressing, a temporary covering, of which dozens of varieties have been used in the past; neither was their new skin merely moved from one place on the body to another, as has been done for decades with conventional skin grafting. Instead, a new skin had been manufactured rapidly from tiny samples, expanding by a factor of thousands, going from human to laboratory and back to human in a little less than four weeks' time.

Dr. Howard Green is a soft-spoken, modest, balding man who looks at you over the top of his glasses and pulls his white coat close as he speaks. It is a windy December day, and we're sitting in the conference room of his penthouse offices in one of the beautiful old marble buildings overlooking the main quadrangle of Harvard Medical School. These are the kind of offices given to the most successful scientists—bright, airy, color-coordinated. Dr. Green was 20 minutes late, and as I sat waiting for him, I tried to decipher the diagram on the blackboard, a large circle with different genes marked off—Pst, PvuII, MstII, Pst—vaguely remembering the biochemistry of gene regulation and looking at large pieces of film spread out on the table—sequences of genes that someone has begun to decode. Dr. Green's secretary told me about the flood of visitors who'd been here before me from all over the world—

Continued on page 78

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MATRIX MATHEMATICS:

HOW TO WIN AT MONOPOLY®

THE MATHEMATICALLY ASTUTE KNOW WHERE TO BUY AND WHAT TO BUILD.

BY DR. CRYPTON

Early in the 1930s, in the midst of the Depression, an unemployed heating engineer named Charles Darrow was sitting at his kitchen table in Germantown, Pennsylvania. His wife was expecting a second child, and he knew that the pittance he made from odd jobs—walking dogs, repairing irons, filling potholes—would not support a larger family. In desperate circumstances such as these, some men spring to action; others retreat into fantasy.

Darrow was a retreater. He started to dream about years long past when his bank account was full and holidays were spent by the sea in Atlantic City. Lost in memory, he scribbled the street names of that seaside resort—Boardwalk, Park Place and so on—all over the tablecloth.

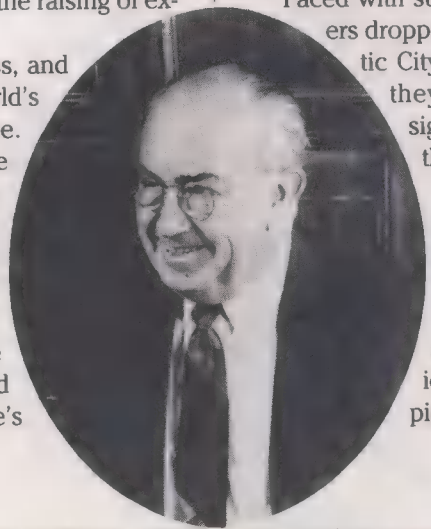
Caught up in reverie, Darrow imagined himself a real-estate tycoon, and somewhere between this fantasy and the streets on the tablecloth, the game of Monopoly was born. At least that's the romantic story perpetuated (and, some say, perpetrated) by Parker Brothers, which took over the game from Darrow in 1935 and made him millions, some of which he squandered on the raising of exotic orchids.

Monopoly was an immediate success, and today, 50 years later, it remains the world's most popular patented board game. Parker Brothers, which prints more "money" annually than the U.S. Treasury, is the world's largest housing developer, having constructed 2.88 billion tiny green houses. Ninety million sets have been sold, in 20 languages, including braille. But the game is not available in the Soviet Union, where it is outlawed as "too capitalistic." Nonetheless, there's reason to believe that at least a few Russians have passed Go: At the American National Exhibition in Moscow in 1959, where Nixon and Khrushchev had their celebrated Kitchen Debate, six Monopoly sets on display mysteriously vanished.

Monopoly has turned the streets of Atlantic City into household words. In 1972, the commissioner of public works there wanted to change the names of Baltic and Mediterranean avenues to Fairmont and Melrose. No sooner was the plan announced than the city leaders were bombarded by letters and telegrams from irate Monopoly players. A group at Princeton University, calling itself Students to Save Baltic and Mediterranean Avenues, threatened to flood the city with Monopoly money if the names were changed. "The streets of Atlantic City, through the medium of Monopoly, have been a microcosm of life," the students declared, "in which Baltic and Mediterranean have represented the last resort of the underdog to hold out against the oppressive forces of Boardwalk and Park Place powermongers."

Faced with such passionate resistance, the city leaders dropped the plan. Today, the officials in Atlantic City are reconciled to Monopoly. Indeed, they are considering painting the street signs and the curbs to match the colors on the game board.

This month, to mark the fiftieth anniversary of the game, Parker Brothers is holding the world Monopoly championship in Atlantic City and New York City. The United States will be represented by Jim Forbes, a 36-year-old Florida accountant who won the U.S. championship last year. He and some 25 other



Engineer Charles Darrow invented Monopoly.

PHOTOGRAPH FROM THE CHARLES DARROW FAMILY/COURTESY PARKER BROTHERS

The right decision, a house on Vermont, nets Dr. Math 1.7 cents more per turn.

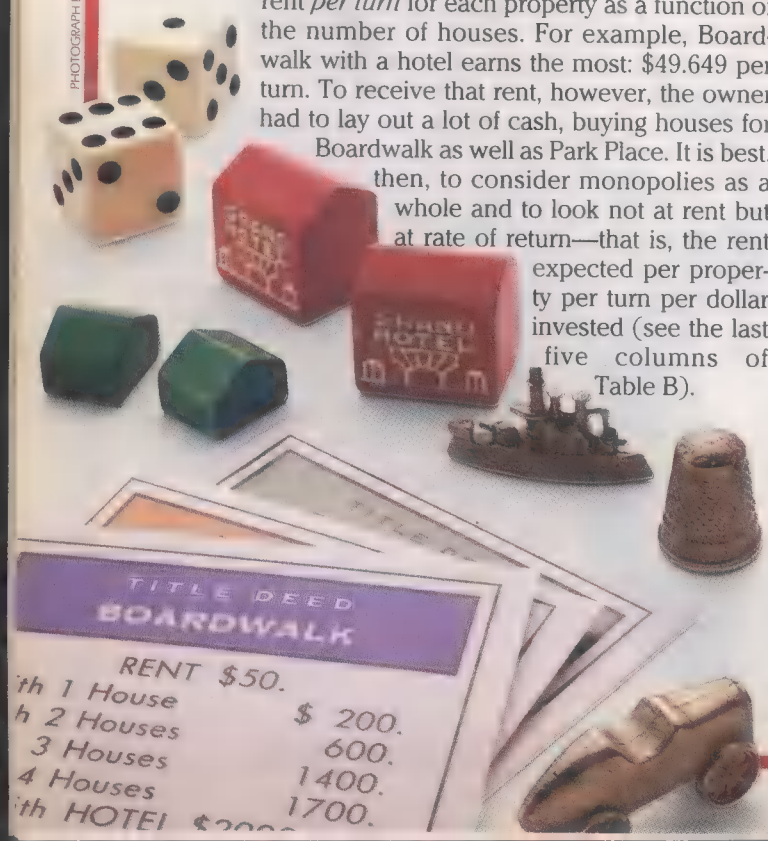
contestants will try to dethrone the reigning world champion, Greg Jacobs of Australia.

Knowledge of the mathematics of Monopoly can help a skillful player make better decisions about what to buy and where to build. At the suggestion of Martin Gardner, the father of modern paradoxology, I have been corresponding with Stephen Heppe, an engineer at Stanford Telecommunications Inc. Thirteen years ago, when Heppe was in high school, he programmed an IBM 1130 mainframe to compute the probabilities of being on each of the spaces of the board. The computation involves the solution of 123 equations in 123 unknowns. (See "The Mathematics of Tedium," on page 70.)

As any Monopoly player knows, when you're in Jail you can either get out immediately by paying $50 or stay put for three turns unless you roll doubles. In the later stages of the game, when houses and hotels are everywhere, it's to your advantage to be in Jail because you can continue to collect high rents without the risk of paying any. (It's true what they say—white-collar crime does pay!) In computing the probabilities, Heppe assumed that the players would stay in Jail as long as possible. The probabilities he found are listed in Table A, opposite, in order of the spaces on the board, starting with Go and moving along clockwise.

By playing around with these probabilities, you'll discover much that's surprising, and you'll improve your game. For example, the probabilities show that you're 49.1 percent more likely to be on Illinois Avenue, the most commonly occupied property, than on Mediterranean, the property visited the least.

The first part of Table B: Revenue shows the expected rent *per turn* for each property as a function of the number of houses. For example, Boardwalk with a hotel earns the most: $49.649 per turn. To receive that rent, however, the owner had to lay out a lot of cash, buying houses for Boardwalk as well as Park Place. It is best, then, to consider monopolies as a whole and to look not at rent but at rate of return—that is, the rent expected per property per turn per dollar invested (see the last five columns of Table B).



PHOTOGRAPH BY MARTHA STANITZ

It turns out that for the Dark Blue monopoly—Park Place and Boardwalk—three houses on each property (for an average rate of return of $0.0293) is a better investment than a hotel ($0.0292). Three houses is also the optimal number for the Green properties: Pacific, North Carolina and Pennsylvania avenues. For the other six monopolies, one does best to build hotels. On the basis of the rates of return, the monopolies (as well as the railroads and utilities) can be ranked in order of desirability:

1. Orange (St. James. . .) $0.0390
2. Light Blue (Oriental. . .) $0.0343
3. Red (Kentucky. . .) $0.0298
4. Maroon (St. Charles. . .) $0.0295
5. Dark Blue (Park Place. . .) $0.0293
6. Yellow (Atlantic. . .) $0.0270
7. The four railroads $0.0266
8. Green (Pacific. . .) $0.0252
9. Dark Purple (Baltic. . .) $0.0229
10. The two utilities $0.0115

Other things being equal, it is advantageous to own (or, at least, to keep opponents from owning) the monopolies that have high rates of return. However, you must not be subservient to the mathematics. Good players know that even the Dark Purple monopoly, the lowest-ranked color group, can be a valuable defensive weapon in a housing shortage.

Two players, let's call them Dr. Math and Mr. Rich, have been playing for a couple of hours. Dr. Math owns the Orange and Light Blue monopolies, on which he has put up 24 of the 32 available houses. He also owns the Dark Purple monopoly, which he refuses to develop because his computerlike mind registers the low rate of return. Mr. Rich, who's loaded, owns the four railroads and the Green monopoly, on which he has erected hotels. He also owns Park Place but not Boardwalk.

Dr. Math is on North Carolina and Mr. Rich is on Go. The gears are spinning in Dr. Math's head. "Aha!" he exclaims. "You're thirty-nine spaces from Boardwalk—the farthest away you can possibly be. I know you want it, but I'll get to it first. I'm only seven spaces away, and seven comes up on the dice more often than any other number. I've got four hundred dollars to spend on buying Boardwalk."

"Hold your horses," says Mr. Rich, "it's my turn first." Mr. Rich throws a seven, lands on Chance and draws a card. "My, my," he gloats. "What have we here? It says ADVANCE TOKEN TO BOARDWALK." Mr. Rich complies, purchases the property, buys the last eight houses for Park Place and Boardwalk and puts up hotels there.

Chagrined, Dr. Math rolls the dice. "Why, it's a seven," Mr. Rich beams, "just what you said you'd roll." Like Donald Trump, Mr. Rich demands $2,000 in rent. Dr. Math can't

Continued on page 71

Dr. Crypton's Science Digest *columns have been collected in* Timid Virgins Make Dull Company and Other Puzzles, Pitfalls and Paradoxes.

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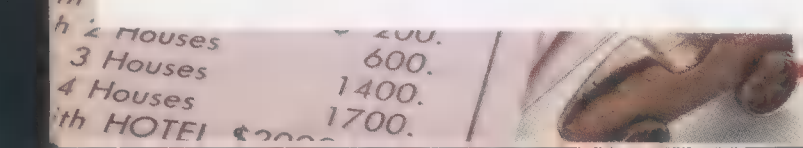


Virginia Make Doll Company and Other Puzzles, Pitfalls and Paradoxes.

MATRIX MATHEMATICS:

THE MATHEMATICS OF MONOPOLY

These tables contain all the data you'll ever want in order to make the mathematically correct plays in Monopoly. Aided by an IBM mainframe, Stephen Heppe, an engineer at Stanford Telecommunications Inc., computed the probabilities in Table A and the revenues in Table B. Mastering them will make you a game-board Donald Trump.

Table A shows the probability of being on each square in Monopoly at the end of a turn. In mathematics, probability is a number ranging from 0 (no chance) to one (certainty). From these probabilities and the stated rents, the revenues in Table B were computed. The first half of the table shows the expected revenue in dollars per turn for one, two, three or four houses or one hotel. Boardwalk with a hotel returns the most money per turn: $49.649. To get a better idea of the value of each property, the cost must be figured in. The second half of Table B shows the rate of return: the dollars you get back each turn for each dollar invested. New York with a hotel has the highest rate of return: 0.04018 dollar per turn, or about 4 cents. (The railroad revenues are based on owning all four.)

TABLE A: PROBABILITY

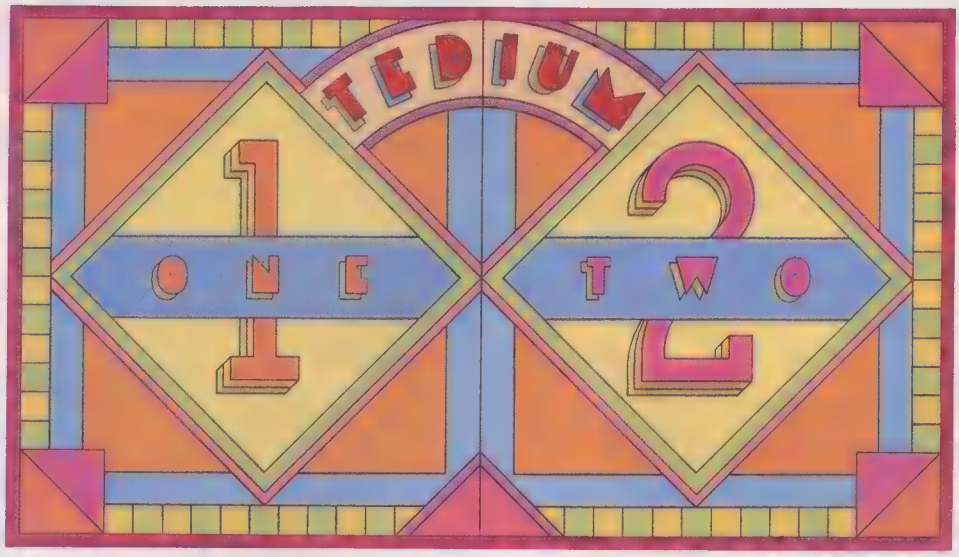
GO	0.02914	NEW YORK	0.02813
MEDITERRANEAN	0.02007	FREE PARKING	0.02826
COMMUNITY CHEST	0.01775	KENTUCKY	0.02615
BALTIC	0.02036	CHANCE	0.01045
INCOME TAX	0.02193	INDIANA	0.02568
READING R.R.	0.02801	ILLINOIS	0.02993
ORIENTAL	0.02131	B.&O. R.R.	0.02894
CHANCE	0.00815	ATLANTIC	0.02537
VERMONT	0.02187	VENTNOR	0.02519
CONNECTICUT	0.02168	WATER WORKS	0.02651
JUST VISITING	0.02139	MARVIN GARDENS	0.02438
IN JAIL	0.09456	GO TO JAIL	0.00000
ST. CHARLES	0.02556	PACIFIC	0.02523
ELECTRIC COMPANY	0.02614	NORTH CAROLINA	0.02472
STATES	0.02175	COMMUNITY CHEST	0.02227
VIRGINIA	0.02426	PENNSYLVANIA	0.02353
PENNSYLVANIA R.R.	0.02636	SHORT LINE R.R.	0.02290
ST. JAMES	0.02681	CHANCE	0.00816
COMMUNITY CHEST	0.02296	PARK PLACE	0.02059
TENNESSEE	0.02822	LUXURY TAX	0.02061
		BOARDWALK	0.02482

TABLE B: REVENUE

	REVENUE PER TURN (DOLLARS)					REVENUE PER TURN PER INVESTMENT (DOLLARS)				
	1 house	2 houses	3 houses	4 houses	hotel	1 house	2 houses	3 houses	4 houses	hotel
MEDITERRANEAN	0.201	0.602	1.806	3.211	5.017	0.00182	0.00376	0.00860	0.01235	0.01618
BALTIC	0.407	1.222	3.665	6.518	9.164	0.00370	0.00764	0.01745	0.02506	0.02956
READING R.R.	5.600	5.600	5.600	5.600	5.600	0.02800	0.02800	0.02800	0.02800	0.02800
ORIENTAL	0.639	1.918	5.755	8.526	11.723	0.00426	0.00959	0.02302	0.02842	0.03349
VERMONT	0.656	1.969	5.906	8.749	12.030	0.00437	0.00984	0.02362	0.02916	0.03437
CONNECTICUT	0.867	2.168	6.504	9.756	13.009	0.00510	0.00985	0.02409	0.03049	0.03516
ST. CHARLES	1.278	2.556	11.503	15.976	19.172	0.00533	0.00852	0.02614	0.02959	0.02956
STATES	1.087	3.261	9.784	13.581	16.310	0.00453	0.00640	0.02224	0.02517	0.02548
VIRGINIA	1.456	4.367	12.130	16.983	21.835	0.00560	0.01213	0.02637	0.03033	0.03308
PENNSYLVANIA R.R.	5.272	5.272	5.272	5.272	5.272	0.02640	0.02640	0.02640	0.02640	0.02640
ST. JAMES	1.877	5.362	14.745	20.107	25.469	0.00670	0.01411	0.03072	0.03467	0.03745
TENNESSEE	1.975	5.644	15.520	21.164	26.807	0.00705	0.01485	0.03233	0.03649	0.03942
NEW YORK	2.250	6.188	16.876	22.501	28.127	0.00750	0.01547	0.03375	0.03750	0.04018
KENTUCKY	2.384	6.538	19.985	23.882	27.458	0.00636	0.01257	0.03522	0.03670	0.02831
INDIANA	2.311	6.417	17.974	22.468	26.961	0.00625	0.01234	0.02683	0.02740	0.02780
ILLINOIS	2.993	8.980	22.451	27.690	32.928	0.00768	0.01563	0.03256	0.03296	0.03326
B. & O. R.R.	5.784	5.784	5.784	5.784	5.784	0.02896	0.02896	0.02896	0.02896	0.02896
ATLANTIC	2.284	6.343	17.762	22.202	26.642	0.00557	0.01133	0.02502	0.02582	0.02638
VENTNOR	2.267	6.298	17.635	22.044	26.453	0.00553	0.01125	0.02484	0.02563	0.02619
MARVIN GARDENS	2.926	8.777	20.724	24.990	29.257	0.00680	0.01513	0.02839	0.02840	0.02840
PACIFIC	3.280	9.84	22.707	27.753	32.168	0.00656	0.01406	0.02525	0.02523	0.02474
NORTH CAROLINA	3.214	9.64	22.248	27.192	31.518	0.00643	0.01377	0.02472	0.02472	0.02424
PENNSYLVANIA	3.530	10.589	25.591	29.236	32.942	0.00679	0.01471	0.02559	0.02521	0.02496
SHORT LINE R.R.	4.576	4.576	4.576	4.576	4.576	0.02288	0.02288	0.02288	0.02288	0.02288
PARK PLACE	3.603	10.294	22.647	26.765	30.883	0.00655	0.01373	0.02384	0.02327	0.02288
BOARDWALK	4.965	14.895	34.754	42.202	49.649	0.00827	0.01862	0.03475	0.03517	0.03546

MATRIX MATHEMATICS:

THE MATHEMATICS OF TEDIUM



TEDIUM BOARD AND ACCESSORIES DESIGNED BY JACK TOM

In his analysis of Monopoly, Heppe relied on the matrix, a mathematical concept that is as powerful as it is simple. A matrix is no more than a collection of numbers arranged in a rectangular array. Matrices are routinely used in quantum mechanics, astrophysics and all other branches of science that involve the manipulation of large quantities of data. To introduce you to matrices, I have invented a thrilling game of solitaire called Tedium. The way I'll analyze Tedium is analogous to the way Heppe analyzed Monopoly—only I'll keep track of four numbers as opposed to the 15,129 numbers that he had to follow.

The game board for Tedium has only two squares, aptly referred to as One and Two. The player simply moves back and forth between the squares according to the roll of a two-sided die (the sides come up equally often), one of which says MOVE ONE SQUARE and the other of which says STAY PUT.

Pretty tedious, eh? To jazz up the game, I've introduced a deck of cards. OK, *deck* is an exaggeration. There are only two cards: MOVE ONE SQUARE, BUDDY and STAY PUT, BUDDY. Whenever the player lands on square One (by moving from square Two), he draws a card and does what it says. He then replaces the card in the "deck" and shuffles, so that there's an even chance of drawing either card. A turn in Tedium consists of rolling the die once, moving accordingly and, if the move is to square One, drawing a card from the deck and following the instructions.

Tedium theorists want to know the probability, in a given turn, of switching squares and of ending up on the same square. Such probabilities depend only on a player's current location on the game board and not at all on how he got there. A mathematical system in which the probabilities depend only on the here and now rather than on history is called a Markov process. The flipping of an honest coin is another Markov process; the probability of getting heads—namely, 0.5—on any given flip is not affected, say, by the coin's having come up tails on the two previous flips.

When the player starts a turn on square One, the cards are not a factor. Thus the probability of staying on One is 0.5, as is the probability of shifting from square One to square Two. Following the notation of the mathematical cognoscenti, we'll designate these probabilities by the symbols $a_{1,1}$ and $a_{1,2}$ where, in general, $a_{i,j}$ is the probability of, having begun on square i, ending up on square j.

The values of $a_{2,1}$ (the probability of shifting from square Two to square One) and $a_{2,2}$ (the probability of staying on square Two) are also easy to find, even though the cards are a factor. Half the die rolls will let the player stay on square Two, while the other half will move the player to square One. Yet, upon landing on One, the player draws a card, which half the time sends him back to Two. So, at the end of the turn the player is on Two three-quarters of the time and on One a quarter of the time; thus $a_{2,2}$ is 0.75 and $a_{2,1}$ is 0.25.

These probabilities can be arranged in a matrix (call it P):

$$\begin{bmatrix} 0.5 & 0.5 \\ 0.25 & 0.75 \end{bmatrix}$$

The entry in the ith row and jth column is designated $a_{i,j}$.

Like numbers, matrices can be added, subtracted, multiplied and divided. But to multiply a matrix such as P by itself, you do not simply multiply each number in the matrix by itself. The number $a_{i,j}$ in the matrix P^2 is obtained by multiplying each element in the ith row of P by the corresponding element in the jth row of P and adding these products.

All this is easier done than described. To find $a_{1,1}$ of P^2, you perform the following calculations (based on multiplying P's first row by its first column): $(0.5 \times 0.5) + (0.5 \times 0.25) = 0.25 + 0.125 = 0.375$. The other three numbers are computed in a similar way, yielding the matrix P^2:

$$\begin{bmatrix} 0.375 & 0.625 \\ 0.3125 & 0.6875 \end{bmatrix}$$

Each element in position i,j of matrix P^2 represents the probability of, having begun on square i, ending up on square j in *two* turns. Thus, 68.75 percent of the time, a player who begins on square Two will still be there after two turns. By the same token, matrix P^3 (P multiplied by itself three times) represents the probabilities after three turns; matrix P^4, the probabilities after four turns, and so on.

Something very curious happens after you reach P^8:

$$\begin{bmatrix} 0.3333 & 0.6667 \\ 0.3333 & 0.6667 \end{bmatrix}$$

When you determine P^9 by multiplying P^8 by P, you find that P^9 is P^8. What does this mean? It means that after eight turns the probabilities don't change. So far, we have looked at *transitional* probabilities—the likelihood of switching from one square to another. In P^8, we are looking at *steady-state* probabilities: the likelihood of being on one square rather than the other. After eight turns, the player will be on square One 33.33 percent of the time and on square Two the other 66.67 percent of the time. These probabilities do not depend on which square the player began the game.

Heppe used a similar procedure to find the steady-state probabilities in the game of Monopoly, only his matrix has 123 rows and 123 columns. It might seem that the matrix should have only 40 rows and 40 columns, since a Monopoly board has 40 squares. But there are two complications. Since being imprisoned is a different state from "just visiting," Jail is effectively a forty-first location. Moreover, it is necessary to keep track of the number of doubles a player rolls in a row, since three doubles send him to Jail. For each square there are three conditions of doubles (none, one and two), and so a player can be in 123 distinct states, which translates into a 123-by-123 matrix.

The number in position i,j represents the transition probability of switching from state i to state j. A 123-by-123 matrix has 15,129 entries. Luckily for Heppe, many of these are zero, reflecting the fact that it is impossible to move from certain squares to certain others. In filling in the matrix, Heppe did what I did for Tedium, only his task was complicated by six-sided dice and two robust decks of cards.

To find the steady-state probabilities, Heppe could have multiplied his matrix by itself again and again until the entries didn't change. This procedure, however, which was successful in Tedium, would have been too time-consuming, even for a computer. (To determine a single entry in the matrix P^2 for Monopoly would require multiplying 15,129 pairs of numbers and summing the results.) Instead, Heppe relied on the mathematical fact (for Tedium, too) that the steady-state probability matrix would yield itself when multiplied by the transition probability matrix. Heppe's program came up with the steady-state probabilities in about 10 seconds. The probabilities take effect after about 25 turns. ■

The 123-by-123 matrix for Monopoly has 15,129 entries, but many are zero.

pay it, so he loses.

How could Dr. Math have avoided this fate? Before Mr. Rich threw the dice, Dr. Math should have used the $400 to buy eight houses for Baltic and Mediterranean. Then there'd have been no houses for Mr. Rich to buy had he been lucky enough to acquire Boardwalk. (The rules require that actual houses be erected before hotels.)

Even neophyte Monopoly players know that of the properties in a color group, the last one always has a higher rent and, hence, is the place to build first. But only Dr. Math and others of his ilk know where to place the second house in the six monopolies composed of three properties. Suppose Dr. Math owns the Light Blue monopoly and has put a house on Connecticut. Should he put the next house on Vermont or Oriental? The expected rents in Table B provide the answer. The expected rent for a house on Vermont is $0.656 per turn, as opposed to $0.639 per turn for a house on Oriental. The correct decision—putting the house on Vermont—nets Dr. Math 1.7 cents more per turn.

On the Light Blue monopoly, houses should be put up counterclockwise, as they should also be on the Orange monopoly. For the Maroon, Red, Yellow and Green properties, houses should first be put up on the last property, then on the first property and finally on the middle. The more houses, the costlier a wrong decision is. The money lost by putting a hotel on States Avenue rather than St. Charles Place is $2.863 per turn. Now, $2.863 may not sound like much, but think of the fear you will strike into your opponent's heart when you announce that you have made the mathematically correct decision. ■

WIN A DELUXE MONOPOLY SET

Serious puzzle and game savants are often obsessed, particularly during bouts of insomnia, with finding the shortest possible game of checkers, backgammon, Monopoly, and so on. With this in mind, I leave you with three problems, which I'll answer in a future issue. The first 20 readers who send me the correct solutions will win from Parker Brothers a special fiftieth-anniversary edition of Monopoly or a commemorative set that replicates the original board, tokens and wooden houses. Send your answers to Dr. Crypton's Monopoly Puzzle, *Science Digest*, 888 Seventh Avenue, New York, NY 10106.

1. What is the shortest possible Monopoly game for two players who receive property only from the bank (that is, not from each other)?

2. What is the shortest possible Monopoly game for an unlimited number of players—call that number n—who receive property only from the bank?

3. What is the shortest possible Monopoly game for n players when all the rules of Monopoly are in force? In other words, players can buy, sell and trade properties among themselves. Although the two previous shortest games could be played by rational beings, this one could not. ■

PHOTOGRAPH BY MARTHA STANITZ

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Following World War II service in Europe, where he escaped occupied France to become a double ace, Yeager stuck with the peacetime Air Force. Despite his lack of a college education, his formidable skills landed him in the cockpit of the Bell X-1 for its historic 1947 flight. Once past the sound barrier, though, Yeager seldom slowed down.

Yeager: The quintessential test pilot.

Now retired (as a brigadier general), Yeager modestly dismisses Wolfean conceits about "the right stuff." Nonetheless, the story of his achievement-filled life, which makes lively, frequently inspiring reading, suggests otherwise.

QUANTUM REALITY: BEYOND THE NEW PHYSICS

By Nick Herbert

Metaphysics, pure old-fashioned ponderings on the nature of the really real, forms the subject of this unflagging excursion by quantum physicist Herbert. It is not news that the world of the infinitesimally small has been riddled with paradoxes ever since Heisenberg established the uncertainty principle and others provided the essential credentials for the dual nature—particle and wave—of quantum matter, or "quons," as Herbert calls them. Perhaps Richard Feynman has the last word: "I think it is safe to say that no one understands quantum mechanics." Herbert makes an engaging try that should open discussion among students and colleagues but may just leave lay readers lost in superluminal fog. *Anchor/Doubleday, 1985. HB: $15.95. 268 pp.*

THE QUEST FOR SS433

By David H. Clark

With the sudden burst of X-ray, radio and better-than-ever optical telescopes, astronomers' eyes and ears are turning increasingly to the true superstars—the supernovas. SS433 appears to be unique in our galaxy (or almost unique; there is dispute), displaying an unusual spectrum and radiating in optical, X-ray and radio frequencies with narrow jet beams that appear to come and go at regular intervals. Could this be a miniature version in our own Milky Way of those mysterious quasi-stellar objects—the extraordinarily energetic and brilliant radio galaxies assumed to be far out in the universe? That is the question. For those who like vivid accounts of science in active progress by an eager expositor not shy about admitting his ambition, a good job. *Viking, 1985. HB: $15.95. 224 pp.*

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An English working geologist demonstrates first-rate skills at laying out a succession of scientific squabbles that have polarized geology from its beginning—circa 1800. First there was catastrophism versus uniformitarianism. Then came the shrinking versus an expanding Earth. Finally, the much-publicized continental-drift theory versus the fixity of landmasses. The consensus today—we have been led to believe—is the version of continental drift called plate tectonics. But to hear Wood tell it, there are more than a few geologists who take issue with today's conventional wisdom. *Allen & Unwin, 1985. HB: $19.95. 240 pp.*

THE WAY OF THE PHYSICIAN

By Jacob Needleman

With our medical system beset with crises and controversies, philosopher Needleman takes on what he considers the most crucial problem of all: the complete collapse of the human relationship between doctor and patient. The doctor-patient interaction remains for him one of the last nontrivial human connections open to modern man. He raises many more questions than he answers—too many. Yet as far as they go, his arguments are poetic and persuasive. *Harper & Row, 1985. HB: $15.95. 187 pp.*

DECLINE AND FAIL: THE AILING NUCLEAR POWER INDUSTRY

By Peter Stoler

A well-researched, insightful, sometimes eloquent account of the troubled development of nuclear power production in America, tracing the history of an industry that grew too quickly under bad management and ended up costing the consumer dearly. To Stoler, a senior correspondent for *Time*, the nuclear power industry is analogous to a problem child spoiled by its parents. *Dodd, Mead, 1985. HB: $16.95. 208 pp.*

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YONAS

Continued from page 34

ployment of defenses, presumably by both the United States and the Soviet Union. At this stage, significant reductions in offensive missile forces could be negotiated. The final phase would be reached when defense deployments are completed and offensive missile forces reach their negotiated low point.

To permit a decision by the early 1990s on whether to advance to the next phase, the Administration requested $1.77 billion for the SDI in fiscal year 1985, up from $0.9 billion in 1984. Ironically, this 1985 request was handed a 20 percent cut by Congress just as the program was getting off the ground in the fall of 1984; thus it began at a level lower than that projected even before the President's speech. The total projected budget for the first five years of the SDI is $26 billion, and the request for fiscal 1986 is $3.7 billion. No attempt was made by the Technology Study Team to estimate the costs for the second phase of the program, but certainly that estimate would play an important role in the decision on whether or not to proceed.

Where might we hope to be in the early 1990s? The tasks faced by any ballistic-missile defense are formidable. To understand the defense concepts and technologies that are being investigated, picture the flight of an intercontinental ballistic missile as passing through four phases—boost, post-boost, mid-course and terminal—each offering different opportunities and challenges to a defense system. A highly effective defense against a massive missile attack would require multiple tiers of defense, countering the offense at each phase until the fraction of warheads remaining was too small to be of military utility.

The Bright Booster

Boost phase is the ideal time to hit a missile. Here the advantage to the defense is that the bright flame from the booster motors can be easily detected by infrared sensors. It provides an aim point for defense weapons to destroy a booster before any of the independently targeted warheads and decoys are released. The challenge is the short time of less than three minutes, which could become even more stressing if the offense expands its missile force or rebuilds its force with radically different features. The long-term approaches to boost-phase intercept involve extremely bright beam weapons that can operate down into the atmosphere and thus respond to even the most advanced threats.

During the post-boost phase, the defense still has an advantage if it can intercept the vehicle, or "bus," before it releases all of the warheads and decoys. The challenge is that the bus's maneuvering engines are much smaller and more difficult to detect than the plume of the huge booster. Both kinetic-energy and beam weapons can be used to attack, and the combination limits effective responses.

In mid-course, the advantage to the defense is the relatively long period when the warheads and decoys can be located and destroyed by space-based and ground-based interceptors far away from such targets as cities or industrial sites. The challenge is that warheads and effective decoys would look more or less alike to sensors. The sheer number of warheads and decoys could swamp the sensors and interceptors unless the defense can discriminate between them. Here again we think that a combination of beam weapons to assist in discrimination, together with kinetic-energy interceptors, would make mid-course an important layer at which to thwart the attack further.

On reentry, the decoys would be separated from the heavier reentry vehicles or burn up, thereby solving the discrimination problem. There is, however, little time to carry out the interception of the warheads the ballistic-missile defense system has missed in the previous phases before they damage or destroy their targets. Moreover, warheads can be "salvage fuzed" to detonate if struck in the upper atmosphere, aggravating the already difficult job of the terminal sensors. The new technologies here involve the combination of a mobile airborne adjunct, ground-based radar and high-performance nonnuclear homing interceptors.

> Our technological capabilities are far from what is needed for a robust defense against Soviet threats.

Many of these boost-phase and reentry-phase technologies are applicable to the shorter range ballistic missiles that pose a threat to our allies as well as to ourselves from submarines off coasts around the world. Despite the much shorter mid-course phase, defense is made simpler by the inability of the offense to field large numbers of decoys in the time available.

Clearly, our present technological capabilities are far from what is needed for a robust defense against plausible Soviet threats and countermeasures in the future. Some of these shortcomings the study teams regarded as critical; unless they could be overcome, there could be no certainty that a robust defense could be achieved. These vital areas include: mid-course discrimination; low-cost interception and destruction, using directed-energy and kinetic-energy weapons in the boost phase; battle-management hardware and software; and survivability of predeployed space assets in the face of direct attack by antisatellite weapons.

By no means does this short list of critical challenges exhaust the range of matters that must and will be addressed in the research program. A whole set of support programs, for instance, must be pursued: determination of generic means for hardening boosters and the lethal effects of various weapons against those means (because we are not likely to get specific engineering design data on Soviet boosters); development of multimegawatt, space-based electrical power supplies, nuclear and nonnuclear, for weapons, sensors and computers; and development of low-cost, heavy-lift space launchers capable of carrying perhaps 100 tons or more to orbit, rather than the space shuttle's current capability of 20 to 30 tons, at one-tenth the cost.

Come One, Come All

As the research program evolves, new discoveries are likely to be made that may radically change the emphasis of the defense program. It is thus vital to stimulate, encourage and fully investigate innovative approaches as early as possible in the program. These new ideas may arise from totally new sectors of the scientific and technical community, sectors that may not even be aware at the moment of the technical challenges we face. To stimulate the broadest involvement of technical talent from government, industry and universities, the departments of Defense and Energy are providing specially earmarked funds to encourage the investigation of radically different concepts that offer enhanced capabilities, although bearing the admittedly higher risks associated with unexplored approaches. In addition, the Secretary of Defense has given our allies an opportunity to participate in the research, and active discussions to define the appropriate mechanisms for their involvement are under way.

Since our discoveries might aid the offensive countermeasures as well, they could force us to eliminate particular defensive approaches along the way. We need to eliminate all infeasible or impractical defenses as soon as possible in order to focus our efforts. It is therefore essential to approach the overall program at all times with a healthy skepticism, as well as with the creativity associated with the exploration of a new field. With the current pace of technological advancement, and the strong motivation provided by the hope of a more secure and stable future, we believe we are well on our way. ■

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BETHE

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of several thousand miles, in a period of a few seconds, with a precision of a yard or so. Basically, three means of doing this have been proposed: lasers, particle beams and kinetic-energy weapons [sometimes called smart rocks], in which the necessary energy is delivered respectively in the form of electromagnetic energy, beams of atoms or molecules, or lumps of rapidly moving matter. In all of these methods, the energy is delivered from a space platform traveling in low (a few hundred miles) orbit over the region from which the ICBMs are launched or possibly "popped up" from a launcher outside the opponent's boundary at the appropriate time. Depending on details of the orbits, delivery system, distribution of ICBM silos and the like, the number of platforms required to have enough in range at any time is generally agreed to be more, and in certain circumstances considerably more, than 100. In making these estimates, it is usually assumed that every shot by the defensive weapon destroys its target and that the space platforms themselves are invulnerable to attack, either before or during the conflict.

Lasers deliver energy at the speed of light because they *are* light. Optical lasers can be either on the space platform itself or on the ground, in which case the space platform contains a large (five-yard diameter) high-quality mirror to reflect the laser light onto the target. Optical lasers destroy the ICBM by heating the skin of the booster; this takes several seconds, during which the laser spot must be held accurately in place to about a yard or so, obviously a difficult task because the booster in the meantime moves some six miles and may even be designed to have some irregular motion.

X-ray lasers, which are themselves generated by a nuclear explosion, explosively evaporate the booster skin, destroying the booster as though with a hammer blow. The X-ray laser beam cannot be reflected; hence the laser must itself be positioned in space. The X-rays cannot penetrate far into the atmosphere, so must attack the booster after it has risen to about 90 miles.

Particle Beams at War

Particle beams destroy the ICBM booster by interfering with the electronics in the missile-guidance system. Because the Earth's magnetic field bends charged particles, particle-beam weapons are usually assumed to use beams of neutral atoms in order to be accurately aimed. They cannot penetrate deeply into the Earth's atmosphere either, because the atoms in the beam become ionized by colliding with the atoms in the air. The ions in the particle beam are then deflected in the Earth's magnetic field by unpredictable amounts. Therefore, particle beams are also restricted to altitudes above 60 to 90 miles.

Finally, the most commonly discussed kinetic-energy weapons are small, exceptionally fast rockets located on the space platform. Typically, they should deliver a 2-to-10-pound projectile to the target at a velocity of about six miles per second. The projectile will have to carry a terminal homing device as well as some means of lateral acceleration to produce the required accuracy. Kinetic-energy rockets are also limited to high altitudes: When the homing device enters the atmosphere, it heats the surrounding air by friction, and the resulting infrared radiation will blind the homing device to the radiation coming from the booster.

All of the boost-phase interception techniques we have described are vulnerable to countermeasures. They require a space-based platform that can be attacked and is far more vulnerable than the ICBM booster itself. It is therefore generally recognized that any space platform will have to defend itself, either with its own weapon or, more likely, with a separate defensive system optimized for that purpose. To avoid the problems of defending the space platform, it is sometimes suggested that a "pop up" scheme be utilized instead, in which the defensive system is launched, probably from a submarine located near the Soviet Union, only after an ICBM attack has begun. The time and weight constraints on such a scheme are, however, extremely severe. Essentially only the X-ray laser, being of low weight, may qualify.

> A booster that could attain full speed in 50 seconds would be safe from X-ray lasers and homing vehicles.

Many of the boost-phase schemes are only effective when the ICBM booster is above the atmosphere. This makes it possible for a potential enemy to adopt a highly effective countermeasure, namely to design boosters that accomplish the boost in a very short time. The Fletcher Committee, appointed by President Reagan to investigate the technical problems of implementing SDI, received a conceptual design of a booster that would attain its full speed in 50 seconds (instead of three to five minutes for present ICBMs) and at a low altitude, about 50 miles. Such a booster would be safe from attack by X-ray lasers, particle beams or homing vehicles. Optical lasers could still attack it, but since the time available for attack would be much shorter, the number of laser space platforms would have to be greatly increased.

Shortening the boost phase would be especially effective against a pop-up scheme, because the popped-up device would not have time to attain sufficient altitude to get a clear, above-the-horizon line of fire to the booster before the booster was burned out. The fast-burn feature is expected to cost only a moderate amount in payload, perhaps 20 percent. That such boosters can be built was demonstrated by Martin Marietta Aerospace in the early 1970s when it built the Sprint missile as part of the U.S. Safeguard hard-point defense system (which was later abandoned as too expensive). The Soviet antiballistic-missile ring around Moscow, the Galosh, is reported to have an even shorter boost phase.

Hardening of ICBM boosters is also possible, again at modest weight penalties, against both optical and X-ray lasers.

Ultimate Countermeasure

Finally, of course, the ultimate countermeasure consists of building more ICBMs. Unless the incremental cost to the defense of killing an extra ICBM is less than the incremental cost to the offense of building one extra ICBM, the defense loses to proliferation. It is as yet not known, even vaguely, what the defensive schemes that have been proposed would cost. Certainly they are very expensive; estimates by, among others, former Secretaries of Defense Harold Brown and James Schlesinger have ranged up to a trillion dollars. ICBMs, on the other hand, can be built relatively cheaply, especially if they are designed with cost in mind and launched from silos that are not hardened.

Defense during mid-course is somewhat different from defense during boost phase. Mid-course is the phase above the atmosphere, so all of the defensive weapons previously described could, in principle, be relevant. Furthermore, the time and range constraints on the defense are much less stringent. The main problems are the selection of reentry vehicles from decoys and the fact that reentry vehicles are harder to destroy than boosters.

Decoys can be made very effective. For example, at almost no cost in weight, each reentry vehicle can be encased in a balloon, and hundreds of identical balloons without reentry vehicles can be dispensed, too, resulting in a vast number of indistinguishable targets that the defense must cope with. In addition, everything can be enclosed in a cloud of reflecting chaff, depriving the defense of the ability to see individual targets.

Either the defense must shoot at everything, which is difficult with a limited supply of ammunition, or some "active" means of discrimination must be employed. This could entail setting off a nuclear explosion near the targets, sweeping away empty balloons or disturbing each object with a laser and observing how it responds. Again, it will be incremental cost that matters: Can the offense put up more objects more cheaply than the defense can deal with them?

Continued on page 83

Data-Storage Revolution

Iomega Corporation's system could make hard disks obsolete.

BY M. DAVID STONE

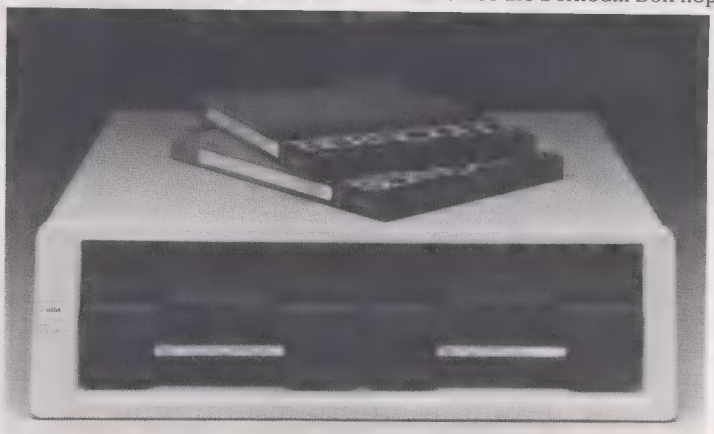
I've just tested a data-storage device called the Bernoulli Box, and I'm an instant convert.

The Bernoulli Box, made by Iomega Corporation, is an external disk-drive unit that contains one or two floppy-disk drives. But Bernoulli Box disks, sealed in individual cartridges, hold 30 times as much data as ordinary floppies—10 megabytes, or about the same as a standard-capacity hard disk. And they're better than hard disks, for several reasons.

■ It's easy to back up your data. Anyone who has lost invaluable information knows how important it is to make copies of everything. There are two ways to back up a 10-megabyte hard disk: Copy the data onto 30 separate floppy disks (an agonizingly drawn-out procedure) or buy a cassette-tape backup system (terribly inconvenient, since you have to reconvert to disk format before you can get to your data).

To copy the Bernoulli Box's cartridge disk, on the other hand, you simply put the data disk in one drive and a blank disk into the other (there is a one-drive model, but since you can't make copies, I wouldn't buy it). It takes about two minutes to copy an entire disk.

■ Storage space is unlimited. No matter what the capacity of a hard disk, it eventually fills up. Since it's an integral unit, with disk and drive sealed into the same box, you have to go out and buy another whole unit. With the Bernoulli Box, you can add storage, 10 megabytes at a time, indefinitely.



The Bernoulli Box takes advantage of 18th-century theories of fluid dynamics to make its floppy-disk drives virtually crashproof. Each disk holds 10 million characters of data, information can be written to and read from it at high speed, and it's easy to copy.

This might not be appealing or appropriate for the average home user, but even the smallest business probably needs it. Remember, 10 megabytes is only about 3,000 typewritten pages of information—not even a filing cabinet's worth.

■ It's nearly crashproof. With a conventional hard disk, the read-write head floats on a cushion of air, generated by the spinning disk, about 20 millionths of an inch above the disk's surface. When the head isn't working, it moves to a section of the disk reserved as a landing zone; when you turn off the machine, it rests on the surface. If the power goes off prematurely, or if a speck of dust breaks the air cushion, the head crashes wherever it is. It removes your data physically, in the form of metal shavings.

It can't happen with the Bernoulli Box, thanks to the Bernoulli effect. Daniel Bernoulli was an eighteenth-century Swiss mathematician; he demonstrated that the pressure in a streaming fluid, that is, a substance that flows, like water or air, gets lower as the stream's speed gets higher. It's the Bernoulli effect in a stream of air that lifts an airplane wing.

The Bernoulli Box takes ingenious advantage of this principle of physics. Its read-write head remains stationary while the floppy disk spins. As the disk gets up to speed, air pressure between disk and head drops. The flexible disk stretches as it is literally sucked down to within four millionths of an inch from the head, close enough for the head's magnets to read and write data. If the power dies or the airstream is interrupted, the disk springs safely away.

■ It's fast, an added bonus of the Bernoulli effect. A normal floppy disk can only spin at about 300 rpm; any faster, and it starts to flutter uncontrollably. A hard disk can spin 10 times faster and, since 10 times the disk surface passes under the head in a given time, it can read and write faster.

But since the Bernoulli Box floppies are held firmly in position by airstream suction, they can go as fast as a hard disk. It took 9.9 seconds for me to copy a 30-page text file onto my IBM PC AT's floppy disk and 3 seconds to copy it onto its hard disk. I was amazed when the Bernoulli Box copied the same file in less than a second.

In short, the Bernoulli Box has a number of advantages over other mass-storage systems, and virtually no disadvantages. There is very little reason to buy a hard-disk drive again.

According to Craig Mecham, manager for marketing communications at Iomega, the basic cartridge-disk technology was developed in the mid-1970s at IBM. "IBM gave up on it," says Mecham, "because they thought it wouldn't work." Three IBM engineers—David Bailey, Rod Linton and David Norton—disagreed. In 1980, they left IBM to form Iomega Corporation.

Iomega's Bernoulli Box isn't cheap, but it's worth the price. The version with two 10-megabyte disks, for the IBM PC and compatibles, has a suggested list price of $3,695 ($3,795 for the TI Professional version), though discounts are widely available. This is in the same ballpark as buying a 20-megabyte hard disk plus a tape backup. A 5-megabyte, single-cartridge version for the Apple Macintosh lists for $1,995. Blank disk cartridges are $199 for a pack of three.

One last note: Iomega has signed an agreement with Tandy to make cartridge disks and drives for Radio Shack computers. Other developments include a newly introduced half-height drive and an upcoming double-sided drive that will hold 20 megabytes per cartridge.

Iomega Corporation, 1821 West 4000 South, Roy, Utah 84067. 801-776-7330. ■

PHOTOGRAPH COURTESY IOMEGA CORPORATION

M. David Stone is the author of several computer books. His latest, The Parents' Computer Book, *has just been released by Prentice-Hall.*

IBM PRINTERS' DEBUT

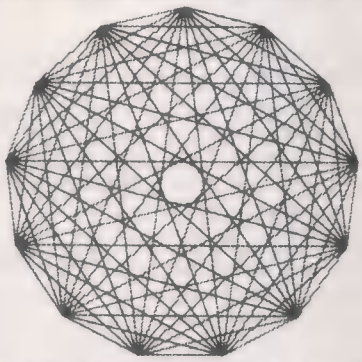
It's no secret that IBM's first printers for the PC market were slightly modified Epson printers wearing an IBM logo. As such, they were almost an afterthought to the IBM PC and were hardly worth comment. Not so the new IBM Proprinter, a $549 dot-matrix printer that is truly an IBM product.

With or without the IBM label, the Proprinter is worth looking at. To begin with, it offers three levels of print quality, with claimed printing speeds of up to 200 characters per second (cps).

The modestly named data-processing quality, at 200 cps, is still suitable for text and is probably better thought of as draft quality. The so-called text-quality mode, at 100 cps, is what is usually called correspondence quality; it is easily readable but is still obviously printed on a dot-matrix printer.

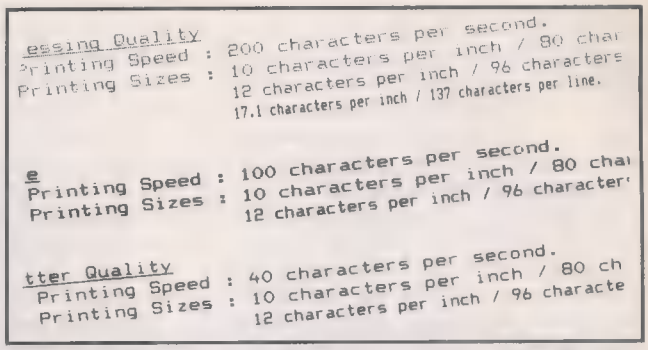
The near-letter-quality output, finally, has a printing speed of 40 cps. This is correspondingly more readable than text quality, though no one is likely to confuse it with output from a Selectric-quality printer.

In addition to the three levels of quality, the Proprinter has all the print capabilities of IBM's earlier printers. This includes such features as superscripts, subscripts, condensed printing at 17.5 cps, expanded printing at 5 cps, underlining and boldfacing. It also has graphics capabilities.



The new Proprinter handles graphics, as well as three levels of text.

Perhaps most important, the Proprinter is almost entirely compatible with the now discontinued IBM Graphics Printer. This means that it will work with virtually all software written for that printer.


essing Quality
Printing Speed : 200 characters per second.
Printing Sizes : 10 characters per inch / 80 char
12 characters per inch / 96 characters
17.1 characters per inch / 137 characters per line.
e
Printing Speed : 100 characters per second.
Printing Sizes : 10 characters per inch / 80 char
12 characters per inch / 96 character
tter Quality
Printing Speed : 40 characters per second.
Printing Sizes : 10 characters per inch / 80 ch
12 characters per inch / 96 characte

Above: data-processing-, draft- and near-letter-quality printing.

The Proprinter has one other feature that you will particularly appreciate if you still keep a typewriter nearby for addressing envelopes. The printer has both a pin-feed roller for continuous paper and a front-loading slot for single sheets and envelopes. This lets you feed in a single envelope without having to remove the continuous-form paper first and then reload it after. It's a minor touch, perhaps, but a welcome one. And its pin-feed mechanism—the *raison d'être* for those little holes on the edges of computer paper—is so situated that when you tear off a printed sheet, the next sheet is ready to go. (Virtually all other printers require you to use that next sheet to position the *following* sheet.)

Another noteworthy machine is IBM's Color Jetprinter, announced at the same time as the Proprinter. The Jetprinter uses ink-jet technology, spraying ink onto paper in tiny, precise spurts. It was not available for review at this writing, but IBM's demonstrations of the printer are impressive.

The Color Jetprinter can print graphics with up to 19,200 dots per square inch, and it can print text at 33 cps in draft mode or 20 cps in near-letter-quality mode. Most important, though, is that the output looks gorgeous. If you're thinking about a color printer, this one deserves a close look. ■

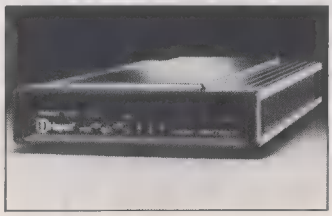
NEW PRODUCTS

The Smartboard, by Wico.

Top-of-the-line keyboard: Wico's Smartboard is one of the latest in a growing line of replacement keyboards for the IBM PC. The Smartboard uses the Selectric-style layout (the original PC keyboard doesn't) and adds indicator lights to the caps-lock and num-lock keys. (The num lock switches the numeric keypad between numbers and cursor control.) In addition, it adds two new wrinkles: a trackball and programmability.

The trackball, built into the keyboard itself, is what is known as a pointing device; you can use it instead of cursor keys. Unlike a mouse, it doesn't need clear space on your desk. Programmability means that you can redefine any key on the keyboard. This feature has long been available in various utility programs, notably ProKey and SmartKey. But with Smartboard, the feature is built into the hardware.

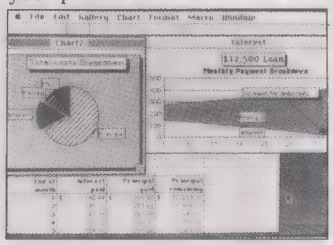
List price on the Smartboard is $300. An Apple II, II+ or IIe version should be available by the time you read this. For information, write or call Wico Corporation, Consumer Division, 6400 West Gross Point Road, Niles, IL 60648. 312-647-7500.



Hayes' Transet.

Three peripherals in one: The Hayes Transet 1000, from Hayes Microcomputer Products, is a combination T-switch, communications buffer and printer buffer—$399.

T-switches, or transfer-switches, let you connect two devices to one. You can, for example, connect your computer to both a printer and a modem through the Transet and switch the computer between printer and modem as needed. In addition to its switching capability, Transet has 128K of memory. This means you can send a file to the Transet at a much higher speed than your printer or modem can accept. The Transet will hold the file in memory and send it to the printer or modem at the appropriate speed. Meanwhile, your computer is free to work on something else. Finally, the Transet can function as an electronic mailbox. Leave it and your modem on, and the Transet answers the phone and accepts text messages—even if your computer is off. For information, call 404-449-8792.



A sample from Microsoft's Excel.

Blockbuster spreadsheet: Microsoft Corporation has unveiled Excel, for the 512K Apple Macintosh; with 256 columns and 16,384 rows, it offers 4-million-plus cells for data.

Excel lets users move data in three dimensions, from one spreadsheet to another, related one; it offers two-way file compatibility with Lotus 1-2-3, and it translates numerical data into graphs and charts with ease. The most exciting function is user-defined macros. Any frequently repeated set of instructions can be recorded by Excel and performed at the touch of ■ key. Excel was announced in May, but is just being released this month. For information, call 206-828-7400. ■

PHOTOGRAPHS: LEFT COURTESY WICO CORPORATION; MIDDLE COURTESY HAYES MICROCOMPUTER PRODUCTS, INC.; CHART COURTESY THE WAGGENER GROUP

SKIN

Continued from page 65

journalists, film crews, researchers, to all of whom he had patiently told the story of his decade of struggle over just that question: How do you grow new skin? And now, after apologizing profusely for his lateness, he begins to tell me.

Colonies of Strange Cells

"It began in 1974," Dr. Green says. "We were studying the differentiation of cells. A graduate student of mine was doing some experiments on fibroblasts [a type of connective-tissue cell], and we noticed some colonies of strange cells in the cultures. It turned out they were a type of squamous epithelial cell. It had been known for over fifty years that skin cells didn't grow well in culture, but we wondered if they would grow under these special conditions."

Dr. Green and his team got a supply of skin cells from a hospital and found that they *would* grow if a layer of fibroblasts were added to the culture. The fibroblasts were treated with radiation so they themselves couldn't divide, but could continue making products the epithelial cells needed for growth. Between 1975 and 1980, a "cocktail" of other growth-stimulating factors was added by a process of trial and error—including epidermal growth factor and cholera toxin, which, they learned, would also promote epidermal growth—and finally Green's team was able to reliably produce sheets of epithelium in the laboratory. By 1979 the system was ready to test on animals—on athymic mice, which have no thymus glands and so don't reject foreign tissue. The cultures of human epithelium grafted to them took and generated a human epidermis. A year later, the team was ready for trials on humans with less than one percent of their bodies burned. Dr. O'Connor, then at Brigham and Women's Hospital, Boston, made the first of these tests.

"We then did about ten [human] cases," says Dr. Green, "each time increasing the size of the area grafted. We had gotten up to about five percent of body surface by two years ago—we were going to go to ten, fifteen, twenty. But then, in July 1983, the two boys came in with over ninety-five percent burns."

This is the part that's familiar from the news stories: the freak accident, the doctor in Colorado who had serendipitously read of Dr. Green's work and arranged the transfer to Boston, where the boys were hospitalized at Shriners Burns Institute, stabilized medically, covered with cadaver skin and artificial membranes and then, over a period of five months, grafted on half their body surface with skin grown in the laboratory. It is the kind of break an actor might dream of—the male lead develops laryngitis, the show must go on—but which the scientist, deliberate, conservative, methodical, often fears. In the glare of publicity there's a need for drama, for instant results, for miraculous cure—and a risk of public and professional humiliation. All of which makes the Harvard team's technique even more remarkable: Not only did it fulfill the demands of public drama, it was also a bona fide breakthrough. The boys, Dr. Green tells me now, are home with their family in Wyoming. They can walk, and both of them are back in school. "Of course, they have no sweat glands or hair follicles," Dr. Green adds. "Overall, the results are comparable to conventional graft results."

We get up and walk down the hall to the laboratory, where a small-statured black man with a mellifluous Nigerian accent greets me. He is Olaniyi Kehinde, an associate in physiology, who has worked with Dr. Green for 17 years and has done much of the actual growing of the cells. Dr. Green leaves us, and Mr. Kehinde takes me over to a lab bench, where, to accommodate the tide of visitors, he has made up and laid out a series of bottles to show the process by which new skin is created.

The plastic bottles lying on their sides on the bench are about four by six inches, the approximate shape of a liquor flask you'd sneak into a football game in your breast pocket, and the skin cultures inside have been dyed purple so you can see them with a microscope. Mr. Kehinde begins to explain the process of growing skin. They start with a square centimeter of skin from any part of the patient that has not been burned. They cut it up fine, "digest" it with enzymes so that the pieces of tissue are separated into single cells, then spread it out on a culture medium. It's funny—as he talks, I feel oddly disappointed. The procedure seems so . . . so *easy*, so low tech. Bottles, enzyme solutions, incubators—somehow I'd expected something futuristic, something out of *2010*, with coils of tubing, flashing lights, computers, something as momentous as the hush of an operating room during a heart transplant or the glide of a spacecraft through the heavens. But this room, pleasant and quiet, has, more than anything else, the contented calm of a hatchery, a greenhouse, a bakery.

Enzymes Take Sheets Apart

"A certain percentage of the cells," says Mr. Kehinde, "make a colony. In about ten days, the colonies have grown together into a single sheet that fills the inside surface of the bottle. We use an enzyme to take the first set of sheets apart, and we make another set from that. From a single biopsy we can make enough to cover the entire body of an adult human being in twenty-four days."

Mr. Kehinde picks up one of the flasks, puts it under the microscope. I squint. At first I can't see anything, then I make out the practically invisible cells clinging to the plastic, sheets of round, flat cells that look somewhat like fried eggs. The spindly stretched-out forms of fibroblasts dance around them.

"The sheet, like skin," says Mr. Kehinde, "has a polarity to it." On the bottom are proliferating cells, and on top are terminally differentiating cells. It has to be put down the right way on the graft area or it won't grow, he says.

Mr. Kehinde removes the sample from under the microscope and puts it back in its proper sequence on the lab bench. He laughs. "What stifled the operation ten years ago was that we didn't know how to get the sheet out of the dish. For two years I labored with frustration. We started looking for a needle in a haystack." Kehinde tested scores of enzymes, looking for one that would break the bond between the cells and the plastic, but not the bonds between the cells. Finally, he read in *Nature* about the enzyme Dispase. "A Japanese group described it. It didn't work for what they described it for, but it did take the cells off the plastic as a sheet."

Once the sheet of cells is removed from the plastic flask, says Mr. Kehinde, it's clipped to a layer of Vaseline-impregnated gauze for support, then taken to the hospital; there, with gauze side up, it's sutured to the burn area. After about 10 days, the cells stick well enough that the gauze can be removed.

> Amazingly, the cells start growing; more and more layers are formed, as pink as healthy skin.

And, amazingly, the cells start growing; more and more layers are formed. Mr. Kehinde opens a photo album to show me the results. A week after the operation, a filmy sheet can be seen on a bloody red surface. By 14 days, it looks crusty; by several months, the skin is thick and fleshy. Some spots look thin, almost transparent, but others are as pink as healthy skin. Most interesting, compared with the ridged, heaped-up look of conventional grafts, these grafts flow smoothly together.

Dr. Green's technique of skin culturing, revolutionary as it may be, is hardly the ultimate answer for burn patients. Despite the enormous amount of fanfare, despite the hundreds of pilgrims coming to pay their respects at the site of its creation, despite the large number of research teams around the world that are beginning to duplicate it in their own laboratories, the technique is still experimental.

One problem is the delay. It takes a minimum of three weeks to get a large amount of graftable epithelium from a small biopsy. And during that time, the severely burned patient may have suffered any of the numerous complications of

skinlessness, and may even have died. Green and his coworkers are trying to prevent some of these complications by optimizing the timing of transplants: If they can make enough skin and have it all ready at once, the transplants can be done at one time rather than in waves, over a period of weeks. Yet inevitably, their method involves a certain delay.

One solution to this problem is being attempted by a research group at New York Hospital–Cornell Medical Center in Manhattan. John Hefton, an immunologist, and a surgical team including Dr. Jerold Finkelstein and Dr. Michael Madden have developed a technique that uses *cadaver* skin, which can be grown and stored in large quantities and kept in skin banks. They are concentrating on outwitting the immune system, which normally rejects foreign tissue. If they are successful, as they hope to prove shortly, it would be possible to transplant new skin onto a burn patient very rapidly.

Skin Grafts from Cadavers

I visit Dr. Hefton's laboratory in New York Hospital on a gray afternoon, as he is busy finishing a grant application. Dr. Hefton, a tall, elegant man, pulls himself away from his work, and we sit on lab stools in the middle of his laboratory, trying not to disturb the other researchers working at their benches.

In the past, Dr. Hefton explains to me, grafts from cadavers have been used only as a temporary covering for burns because of the inevitable process of rejection. But his team, by using the enzyme DNAse I, believes it can remove one type of skin cell, Langerhans' cells, that triggers that process.

Rejection is triggered in two steps, by class I and class II antigens, the protein markers that signal a foreign presence in the body. In skin, the class II antigens are found only on Langerhans' cells; and in DNAse-I-treated cultures, there are no class II antigens. Therefore a state of "partial tolerance" may be created, whereby transplanted cells can continue to live in a foreign terrain. So far, Dr. Hefton tells me, they've done experiments on mice, guinea pigs and domestic pigs showing that such grafts can last at least three months after transplant, which is as long as they've been followed.

Dr. Hefton takes me into another room and shows me his collection of skin cultures, sitting in flasks in an incubator: I peer through a microscope at his cells. For all the world they look just like Dr. Green's, though, as Dr. Hefton explains, they are made to grow in an entirely different way: no fibroblasts, no cocktail of growth factors, but a careful control of temperature, pH and "seeding density"—the number of cells placed per square centimeter. This method, he says, produces cultures that grow up to 20 cell-layers thick and are very skinlike, with well-differentiated cells, even before transplantation. This may make it easier for the cultures to grow after they are transplanted.

I look up from the microscope. What about human trials, I ask. How well does such a system work in humans?

Dr. Hefton is reluctant to answer. They have begun human trials, he says, but he can't tell me many details of their results, since they have only published one article in a scientific journal. All he can say now is that in about 25 patients "we've grafted large areas" and have "observed seventy-five percent healing," and that the team is now working with colleagues at Memorial Sloan-Kettering Cancer Center, analyzing tissue antigens to prove that the grafts have taken. Interestingly, says Hefton, they've observed healing similar to that which Dr. Green's group has reported; there's a minimum of scarring where the grafts have been placed, and very little contraction. His team expects to publish these results in the near future, and if it can be proved that the technique works, Dr. Hefton predicts there will be a revolutionary change in the way burn patients are treated—that banks of cultured skin will be established from which burn patients can receive transplants very shortly after they are admitted to the hospital.

Other researchers, I know, are skeptical that such a technique would work. Pointing out one problem, Dr. Green says, "It needs to be proved that the cells taken from other donors and therefore possessing foreign antigens remain permanent after grafting. Antigens lost in culture may be regained after grafting."

Dr. Hefton tells me he's confident their results will show that such a technique *does* work and that rejection doesn't occur. Actually, he says, the most difficult thing in keeping the grafts alive after transplantation is protecting them from drying out and from being torn or scraped—rejection hasn't been the problem. And until his group publishes its results, that's where the argument stands.

A second possible problem with both the Green and the Hefton techniques revolves around the question of dermis. These techniques replace only the epidermis, the upper of the two layers of skin, while conventional grafts include at least a thin layer of dermis. Some scientists, including Dr. Green, feel that the epidermis generated from cultures will provide a satisfactory skin, but others believe that dermis is essential—that without it, the skin is lacking in strength and in protective ability and will be liable to more contraction as healing proceeds.

One-Step Skin Replacement

The foremost exponents of this view have been another group of Boston-area researchers headed by John F. Burke, a surgeon at Massachusetts General Hospital, and Ioannis Yannas, a professor of polymer science at MIT. In the first stage of their research, they created an artificial dermis. Now they are working on a one-step skin-replacement technique of both dermis and epidermis that can be done in less than two hours and could make the need for skin grafting obsolete.

The Burke-Yannas artificial dermis is very complicated. It has two layers. The lower layer is made of two organic materials found in connective tissue—collagen, a tissue protein, and a polysaccharide, another structural element. The upper layer is a removable sheet of silicone plastic and looks somewhat like the rubber used to make lab gloves. During the process of healing, the lower layer is gradually broken down as the patient's own dermal cells grow in over the wound; eventually the upper layer can be peeled away. Over 55 patients have been treated with such an artificial dermis, Dr. Yannas tells me when I phone him at MIT. The problem with this artificial dermis is that the patients later have to be grafted in the usual way, with conventional epidermal grafts.

Hundred-Minute Procedure

However, Dr. Yannas adds, his group is now testing its one-step skin-replacement technique. After four years of extensive animal testing and "refinement" of the membrane (including adjustment of the proper pore size to allow the patient's cells to colonize the membrane), the new material is now being tried on humans. The artificial dermis is "seeded" with young epidermal cells taken from the patient, which gradually move to the top of the collagen layer and, after 10 to 12 days, form a continuous sheet, a new epidermis. No grafting is required.

"I call it the hundred-minute procedure," says Dr. Yannas. "In the hundred minutes, the burn patient comes in and is stabilized with enough fluids to make up for the great fluid losses. A small piece of skin, about the size of a quarter, is removed. We take the specimen from Massachusetts General Hospital to MIT, a ten-minute drive away. Next we remove the youngest cells and centrifugally drive them down into the membrane. Then we bring the whole thing back to be grafted.

"The graft is bandaged to the patient. After ten days, in the animal model, you see the animal has rebuilt the skin from nothing, from muscle only. Both dermis *and* epidermis are rebuilt." Yannas can't say anything about the human trials yet, but the same thing, presumably, is happening: Within two weeks the burn patient will have a brand new skin. True, it will be lacking in hair follicles, sweat glands and pigment cells, but it will be a living, functional skin. As we talk, Dr. Yannas's enthusiasm grows; you can sense his enormous excitement at finally applying a system that has been in the works for more than a decade. The difference in his group's technique from that used in other labs, he tells me, and the reason he is confident that it will one day become the standard treatment, is this: "We let the animal, in future the patient, prepare its own tissue. Other groups have to wait three weeks. We put the patient right to work."

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VICTORY

Continued from page 49

Soviets move forces into the border area to crush the revolt; NATO commanders move their own divisions forward. As the crisis escalates, communications systems break down under massive overloads.

At this point, scenarios such as that of General Sir John Hackett, author of *The Third World War,* envision the Soviets striking into West Germany with massive force. The United States could not expect NATO forces on the scene to hold out for long. Their task would be to keep the enemy from reaching the Rhine.

Bridging the Atlantic

Troop reinforcements would come by air. The transport aircraft of the Military Airlift Command—C-5A (the world's largest aircraft) and C-141 heavy lifters—would form a bridge across the Atlantic. They would be joined by civilian airliners pressed into service. The main supplies would come by sea, in containers that, once landed, could be transported by railroad flatcar or flatbed truck. Additionally, roll-on, roll-off ships, or Ro-Ros, large seagoing ferries with ramps fore and aft, would be used to carry tanks across the Atlantic. Other Ro-Ros would carry the semitrailers of trucks; by hooking up tractors, these could be driven directly off the ship and onto the European road network. There would be barge-carriers, too, whose barges would be left in port for unloading. Conventional freighters would be employed for heavy equipment and low-priority gear.

The heart of a convoy would be a relatively small number of specialized ships capable of cruising at 20 knots. The container ships and freighters would be particularly inviting targets, "the sort of honey that would attract a lot of Soviet flies," as one analyst put it. As a convoy put out to sea, it would move within a ring of frigates or destroyers to guard against air attack. A second such ring, 60 miles across, would surround the inner ships for protection against submarines. An antisubmarine-warfare helicopter carrier would lead the way. The forward-patrol plane for the entire convoy would be a four-engine P-3C Orion antisub aircraft.

Some analysts have described how the U.S. defense of the shipping lanes would begin far to the northeast off Scandinavia, virtually in Soviet home waters and near their most priceless naval asset, the nuclear ballistic-missile subs. The U.S. strategy would be to rely partly on its largest carriers in a bold advance north of Norway, daring the Soviets to come out and fight. Norman Friedman, formerly a naval analyst with the Hudson Institute, says, "They'll go bananas if we send our carriers there. The Russian doctrine is to hit a carrier with everything at once." The U.S. carriers would then attempt to tie down Soviet forces to keep them from attacking the vital sea-lanes.

The carrier force, together with fighters and interceptors based in Great Britain and Iceland, would take their toll of Soviet bombers heading south. In addition, Soviet subs would be slipping southward, seeking to reach the open Atlantic. They would have to pass through the ocean gaps between Greenland, Iceland and the United Kingdom, known as the G.I.U.K. gaps. There the heart of the U.S. defenses against subs would be anchored, with hydrophones deployed to pick up any sounds of naval movement.

Naval warfare was on display most recently in the 1982 British campaign in the Falkland Islands. The British sent a task force built around two carriers, *Invincible* and *Hermes.* One of their subs sank one of the Argentine's most prestigious ships, the cruiser *General Belgrano.* The Argentineans struck back with fighter planes carrying French-built Exocet missiles, each with a 363-pound warhead. Some missiles found their mark, sinking the destroyer *Sheffield* and the container ship *Atlantic Conveyor.*

All this would be no more than a taste of the violence of a full-scale war in the North Atlantic. "There's almost nothing comparable to the big carriers," says Friedman. By contrast, a carrier such as the *Nimitz* or *John F. Kennedy,* three times larger than the *Hermes,* carries 90 or more aircraft. Many of them are F-14 fighters and F-18 aircraft, used for both attack and for air defense.

Big carriers have great battle endurance. Each can carry 2,000 tons of bombs, rockets and other munitions.

Big carriers have far more battle endurance. Each can carry 2,000 tons of bombs, rockets and other munitions, compared with the 100–200-ton capacity of the *Invincible.* The F-14 has far greater range and firepower than the British Harriers. In addition, U.S. task forces would include E-2 early-warning aircraft. By spotting enemy aircraft beyond the horizon, they would allow U.S. forces to fight a very different kind of war. The British, lacking such airborne warning, were forced to fight at closer range, and Argentine jets could stand off at a distance and launch still more Exocets. The United States could probably capitalize on its early-warning system and the greater range of its fighters to hit the Soviet bombers before they could launch all of their missiles.

While the war in the air would at least bear some comparison with the Falklands, the war on the sea would involve intense antisubmarine warfare. The Navy considers its nuclear-powered attack subs to be superior to any in the world. Their sensitive sonar can track a Soviet sub up to 30 miles away. Such subs would set up a zone defense within the G.I.U.K. gaps, each sub in a specific area. The Navy has other hydrophone arrays as well, to be towed by ships, dropped from aircraft and mounted permanently on the seabed. All these arrays would be linked to computers to extract the telltale sound of a sub from the surrounding noises of the ocean.

Once an attack sub detected its quarry, it would close in and fire an acoustic homing torpedo equipped with sonar. When a hydrophone array reported a contact, naval command in Norway, Scotland or Ireland would respond, sending out a heavily armed P-3C Orion. The response also might launch an attacking aircraft from a carrier or a helicopter from a smaller ship. In the area of the contact, the P-3C or other aircraft would drop sonobuoys, small floating buoys dangling a hydrophone from a wire. These would indicate the direction to the sub. The aircraft or helicopter would then pursue, dropping more sonobuoys. Near the sub, the aircraft would use magnetometers to detect the presence of a large mass of submerged steel. Closing in, they would launch their own homing torpedoes. An explosion deep within the water would announce a hit. It would also dramatically disclose the sub's position, allowing the attackers to launch still more torpedoes to complete the kill.

In the United States, submarine technology is racing ahead: The Office of Naval Research is sponsoring studies at Lawrence Livermore National Laboratory to coat subs with a smooth, rubbery skin to reduce drag. The Naval Underwater Systems Center in San Diego is also studying reduction of drag by injecting polymers into the boundary layer, the thin layer of water that clings to any object moving through the sea. The technique allows water to flow past the hull with less turbulence and hence less drag. Experts at Pennsylvania State University report reducing drag by over 80 percent as a result of injecting micron-size air bubbles into the boundary layer.

Quieter Submarines

Attempts to hamper the detection of subs by reduction of their noise level have been made on a number of fronts. The attack submarine U.S.S. *Lipscomb,* built by the Electric Boat Division of General Dynamics, features direct-drive electronic motors instead of conventional engines with gearboxes. Challenges still remain in quieting the machinery in nuclear plants. The West German firm of Howaldtswerke Deutsche Werft is currently developing fuel cells as an auxiliary source. These amount to highly efficient batteries driving electric motors. Intelligence analysts state that the Soviets are developing fuel cells that can be recharged with the heat or radiation from

a nuclear reactor.

Among American intelligence analysts there have been recurrent rumors that the U.S. civilian satellite, Seasat, unintentionally detected submerged subs. The spacecraft, launched in 1978 as a scientific satellite, carried a battery of radars to scan the sea surface. Its data were accessible to all countries. Designed to serve for three years, it mysteriously went dead after 100 days. NASA's explanation was that it suffered a massive short circuit. Some analysts, however, suspect that the spacecraft saw more than it should have—and, rather than let this method of submarine detection become common knowledge, the leaders of the intelligence community secretly persuaded NASA's directors to shut down Seasat.

Jet-Powered Subs

While the screw propeller has dominated the seas for over a century, it is presently challenged by a new technology—magnetohydrodynamics, or MHD. An MHD jet features a rectangular channel resembling a long hallway. On one set of opposite sides are placed the north and south poles of powerful magnets and on the other set are negative and positive electrodes, with a powerful current passing across the channel. Seawater fills the channel, conducts electricity and can be made more conductive by seeding it with a metal such as cesium. The water then flows rapidly under the action of the electric and magnetic fields, blowing vigorously out the back in a jet. By reversing the electric current, the water jet blows to the front, allowing a sub to stop very quickly. This propulsion system thus offers high speed, maneuverability, exceptional quietness and freedom from vortices.

In the event of war, U.S. forces will have to rely not on weapons in the lab but on those that are ready to be sent to sea. Recently, however, a series of developments have raised alarming questions as to whether our fighting forces indeed have the weapons they need. In July 1984, the House Appropriations Subcommittee on Defense released a report charging that the Navy is "unable to sustain full combat air and surface operations for more than a week's time."

Another report pointed to shortages of key naval aircraft. A congressional source reported that out of 190 F-14 fighters equipped with Phoenix missiles in the Navy's Atlantic fleet, 32 were recently either undergoing maintenance or placed in storage. It was also reported that by 1990 the Navy's carriers face a shortage of as many as 100 S-3 Viking aircraft, twin-jet planes planned as the mainstay of the U.S. carriers' role in antisub warfare.

How critical are these matters? The potential stakes are high. In Norman Friedman's words, "If we can crunch most of the Soviet air and sea forces, that will mean victory at sea. But if they defeat ours, they will cut our sea-lanes. If we lose control of the oceans, we lose the war." ■

THE BUTTON

Continued from page 45

Looking Glass planes recently, I suspect that the general on duty would be gravely concerned about his inability to make contact with U.S. nuclear forces and with the country's surviving military and political leaders. This was suggested in a number of homely ways, most notably when the battle staff mentioned, in passing, the problem they had with one of their critical radio antennas—its tendency to fall off.

There's No One To Talk To

Current hardware problems aside, even perfect communications gear will not solve the plane's most immediate quandary once a nuclear war begins: the lack of informed people with whom to talk. The plane will be included in the conference call with NORAD's commander in which he announces his attack assessment, if he has enough data to make one. The plane is dependent on him for this and cannot carry out a detailed independent evaluation of the nature and extent of any ongoing Soviet attack. Thus, once its contacts on the ground are lost, Looking Glass will be operating blind.

The present strategic command and control system, one of the Pentagon's senior advisers commented, should be a clue to the military's real thinking about nuclear war. The fact that the apparatus for responding to Soviet attack has been allowed to have so many flaws reflects the feeling of "at least nine out of ten people in the military planning system that strategic war wouldn't occur. That belief affects their thinking on command, control and communications requirements." In addition, strong military traditions provide further reason for de-emphasizing the command and control systems needed for nuclear retaliation. Down through the ages, commanders have always favored offense over defense. Permitting the United States to be destroyed by the Soviets, and then retaliating, is a completely unmilitary notion. The common operating premise, therefore, is that the United States would never permit itself to be hit first.

In 1979–80, a series of "Internal Conferences on War Aims and Strategic Forces" took place under the auspices of TRW, a major defense contractor. One of the participants was General Bruce Holloway, former commander in chief of the Strategic Air Command. In a memorandum after the conferences, General Holloway discussed his views on the "conclusions shared by most of the group" as well as some of his own "impressions." The United States "war aims," he wrote, included "prevention of the loss of our way of life," "damage limitation," and the "degradation of the Soviet State and its control apparatus to such an extent as to make successful negotiation possible." In achieving these objectives, "the

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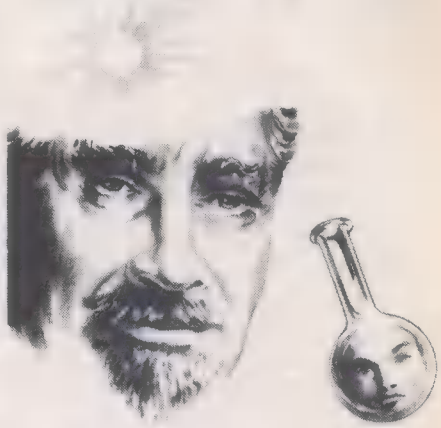
Is Soul Transplant Possible?



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SCIENCE digest

READERS' POLL

The world as we know it can cease to exist in a matter of minutes. This fact of the nuclear age has overshadowed all others for more than three decades.

Arms-control agreements have not succeeded in removing the threat of nuclear oblivion. They have merely controlled the buildup of nuclear arsenals. But hopes have now been raised that where diplomacy has failed, technology may succeed. The proposed Strategic Defense Initiative (SDI), popularly known as Star Wars, is held out as the way to make nuclear weapons obsolete.

Is the SDI just another escalation of the arms race? Should we undertake what amounts to the most massive R&D effort ever contemplated to develop a Star Wars defense? In this issue we have endeavored to present you with pertinent information so that you can develop informed opinions on these and other defense issues. Now let your opinions be heard. Take the time to answer the following poll questions. We will compile the results and provide them to Congress and to President Reagan. Mail your completed questionnaire to:

SDI Questionnaire
Science Digest *Magazine*
888 Seventh Avenue
New York, NY 10106

1. Do you believe that the Soviets would ever be willing to start World War III?	YES	NO
2. If there were a reasonable chance that it would make the United States invulnerable to a massive nuclear attack, should a defensive shield against ballistic missiles be developed along the lines of the President's Star Wars proposal?	YES	NO
3. If it were only able to protect us from attack by a few missiles launched by either a superpower or a Third World country, would you support development of a defensive shield?	YES	NO
4. In either case, would you support a tax increase to pay for research and development of a Star Wars system?	YES	NO
5. Do you believe that a Star Wars defense will fuel a new arms race?	YES	NO
6. Do you believe that our current nuclear arsenal and our long-term policy of mutual assured destruction provide a sufficient deterrent to nuclear attack?	YES	NO
7. If it could be shown that Star Wars would provide a defensive umbrella over the United States, do you believe that the Russians would launch a preemptive strike before it was put in place?	YES	NO
8. Should the treaty prohibiting space-based weapons be scrapped to permit deployment of a defensive shield?	YES	NO
9. Would the country be more secure if the billions of dollars needed to build Star Wars were spent instead on creating jobs, rebuilding obsolete factories and financing R&D to get an edge in emerging technologies?	YES	NO
10. Should the United States build weapons like the MX missile that could give us the capability—at least on paper—to fight a limited nuclear war?	YES	NO
11. Are arms-control negotiations the best way to reverse the arms race?	YES	NO
12. Can we trust the Soviet Union to abide by arms-control agreements?	YES	NO
13. If Soviet conventional forces were to invade Western Europe, should the United States follow its stated policy and retaliate with nuclear weapons if all else fails?	YES	NO
14. If nuclear war seemed inevitable, should the United States launch a preemptive strike?	YES	NO
15. Should the United States formally renounce the first use of nuclear weapons?	YES	NO
16. Should our priorities be changed so that less money is spent on nuclear forces and more money on conventional forces?	YES	NO
17. Is a nuclear war inevitable?	YES	NO

MAN'S QUEST

Continued from page 55

It was not the end of war, of course. The old instincts could still be unleashed. War still could be fought. It could be fought between nations that did not possess nuclear weapons. It could be fought by one nation that possessed nuclear weapons against another that did not and, therefore, could not retaliate in kind, as when Japan could not retaliate against the United States.

An Automated Battlefield

The military applications of electronics thrive. Computers, optical scanners, datalink and telemetry systems have automated the modern battlefield, eliminating human error in the calculation of angles of fire, rates of speed and the direction of targets and reducing delays in responding to target information. Improvements in radio transmission have increased the power, range, flexibility and security of communications systems. Radars to acquire and track targets have revolutionized fire-control systems for missiles and automatic guns.

Missiles are guided not only by radar but also by infrared and electro-optical systems. Acoustic and infrared sensors now locate and identify targets. Magnetic anomaly detectors track submarines in the ocean's upper depths, and arrays of hydrophones detect them at lower depths. Computers and ground-mapping radars can navigate an aircraft or missile, night or day, in any weather, by matching its course with known contours of the terrain over which it flies. Inertial-guidance systems keep some naval vessels and aircraft on course, and computers are ready to help steer ballistic-missile reentry vehicles to their targets.

The newest generations of aircraft, missiles and automatic guns may well represent the highest achievements of modern technological skill. As we continue to develop and improve these weapons, increasing their speed, their accuracy and their destructive power, making them ever more impervious to detection and ever more resistant to countermeasures, we seem bent on controlling fate.

Yet all of our wizardry has not produced the ultimate weapon. It has not made warfare more decisive. It has done the reverse by placing unprecedented levels of destructive power in the hands of almost every nation. This has changed the whole nature of warfare. Every war now promises catastrophic losses.

In destructive power, some conventional weapons now approximate nuclear weapons. Fuel-air munitions, first used in Vietnam, spread highly volatile clouds of ethylene oxide or other fuels over areas hundreds of yards wide. When ignited, they release more than five times the energy of their equivalent weight in TNT. They flatten all structures beneath them and literally shear trees away at their roots. The Israelis may have used small versions of these weapons to collapse buildings in Beirut in 1982.

According to our Department of Defense, the Army's multiple-launch rocket system (MLRS) "can fire 12 rockets beyond cannon range, covering an area the size of six football fields with approximately 7,700 grenadelike submunitions effective against both personnel and lightly armored targets."

It is only a matter of time before every nation has weapons of equivalent power and very high accuracy. There is already so much destructive power in the arsenals of every developed nation that the outcome of conflict has only grown less decisive, as Iran and Iraq continue to learn. The losses from conventional war may soon become no more acceptable than those anticipated from nuclear war.

The only kind of war that has not been fought is war between two nuclear powers, because it remains impossible for either superpower to assure that all its opponent's retaliatory nuclear forces could be eliminated in an attack, no matter how massive or accurate the attack might be. It has been impossible to be certain one's own weapons would behave predictably. It has been impossible to be certain the nation under attack would behave predictably, adhering to its declared policy of waiting for an attack before responding.

It was perfectly clear at the dawn of the nuclear age that war between nuclear powers risked suicide. Then, in 1968, the Soviets deployed long-range ballistic missiles on submarines, creating the same relatively invulnerable retaliatory force the United States had had since it first placed such missiles at sea in 1960. Since that time, there has been not merely an unacceptable risk of retaliation. There has been a virtual certainty of retaliation.

The Dangerous Deception

As the United States prepares to deploy a new generation of even more accurate nuclear weapons, as well as a new defense in space, and the Soviet Union continues to multiply its own redundancies in nuclear arms, U.S. officials continue to perpetrate the deception that we have no plans for a first strike, that only the Soviets do, that deterrence is threatened only by Soviet aggression and not by refinements in nuclear weaponry, and that Soviet aggression can only be met by more refinements. More likely than not, officials in the Soviet Union make comparable claims to promote their own weapons programs.

Perhaps these officials believe that because governments have managed increasing levels of nuclear risk for 40 years, they can continue to do so indefinitely. We must understand such arrogance. The road from deception to self-delusion is short. From the beginning of time, from crossbow to nuclear missile, the history of the arms race has been nothing so much as a cavalcade of self-delusion. ■

BETHE

Continued from page 75

All these difficulties of designing effective defensive weapons pale in comparison with the integration of the defense into a complete system. The battle-management station would have to keep track of some 100,000 objects in mid-course, preferably "from birth to death." It has to assign targets (boosters, warheads, decoys) to individual defensive weapons. And a battle station must assess whether a given target has been destroyed and, if not, "hand it over" from one defensive weapon to the next along the flight path. The computer required for this would be enormously more sophisticated than any yet designed. If it were placed in orbit, it would be susceptible to direct attack, while if it were on the ground, its data link with the enormous establishment of defensive weapons in space could be cut. Furthermore, this entire system could never be tested under circumstances that were remotely realistic.

Unattainable Goal

Our conclusion from all of this is unequivocal: Even if the concepts now under discussion can be turned into operational devices, they will not be able to overwhelm the countermeasures available to the offense, and they will not, therefore, provide a near-perfect defense. And since a partial defense is more dangerous than no defense at all, we believe that the SDI is a program with a goal that is not attainable unless and until there are technical breakthroughs that have not yet been conceived of. Research on the relevant technologies will, of course, continue even if the SDI is abandoned. If, in the future, this research leads to the possibility of a really viable defense, that will be time enough to decide whether or not we want to replace mutual deterrence by strategic defense. In the meantime, mutual deterrence is all we have and all we can have. ■

"Any sign of rain yet?"

CARTOON BY PETER PORGES

STAR WARRIORS

Continued from page 39

announcing all nuclear tests and started keeping the existence of the small ones secret.

"R program per se is focused on X-ray lasers," Tom said in answer to a question. "My feeling has been that if you're going to have a different third-generation concept, it's better to have that be independent in a lean way. We're busy enough trying to do as much as we possibly can with inadequate resources. We're not terribly conservative, and so we're always biting off more than we can chew. It then takes heroic effort by a lot of people to pull it off."

Boost to Arms Control?

Wouldn't a defensive shield create an imbalance between the superpowers? I asked. Our shield would probably be better than the one the Soviets would build at first, even if they eventually caught up. Wouldn't they fear that we might use our shield for offensive purposes to mop up the ragged retaliation after we launched a first strike?

Tom considered this for a moment. "Hopefully it will lead them to serious arms-control negotiations," he answered. "If they think there's going to be an asymmetry that they are going to have a hard time making up, then they are going to ask what they can do to reduce the consequences to themselves. The rational thing, as they did during the first great ABM debate [in the early 1970s], is to try to get us to give it up in a treaty—to say to themselves, 'Here's an area we can't compete in. Let's give it up.' And if we're on the ball, we'll be able to extract things like across-the-board strategic arms reductions and get them to be serious. 'Hey,' they might say, 'isn't it time to try to come to something a little less threatening all around?' I think that's a very credible scenario—as long as we don't saber-rattle and get them so paranoid that they feel the only thing they can do is launch now rather than later. I think they're not that crazy. From what I have read, the Soviet system is reasonably stable and methodical in the way it goes about decision making. I think that their perception of an impending asymmetry will make them more susceptible to negotiation."

It was an evasive but rather elegant answer. Unfortunately, it was also true that failed "bargaining chips" had all too often gone on to accelerate the arms race. The list went on and on—the Pershing II, cruise missiles, the MX and so forth.

"The other issue," Tom continued, "is that if we really think we're going to force them into a corner, we could consider things like sharing technology or setting up a mutual defense system."

I asked Tom whether he thought asymmetry in X-ray laser defense was a real possibility.

"The Russians have certainly pioneered a lot of work on X-ray lasers. So as far as basic science goes, I think that we can't count on us having smarter scientists than the Soviets. Maybe we're better motivated—maybe not. It's hard to say. I like to think we're pretty well motivated. But historically the Russians have been pretty on the ball about catching up."

We were joined by Lowell Wood, the leader of the young scientists of O group, who had been kind enough to let me stay at his house for the length of my visit. Lowell, 42 years old, had known Edward Teller for almost a quarter century. As Teller's main protégé, Lowell now labored mightily in a very personal fashion to carry on the nuclear heritage.

Lowell was the kind of person who inspired either love or hate in those who knew him. I heard the range. He had been called rude, crude, sarcastic, arrogant, cocky, crazy, irresponsible and abrasive. He had also been called clever, smart, loyal, witty, patriotic, creative, sensitive and deft. From my limited experience, he clearly had a lot of energy. He talked incessantly and was filled with that old-fashioned can-do spirit.

> Battle management and command and control are difficult. You need reasonably autonomous intelligent platforms.

The two scientists had differing opinions on many aspects of their programs. Tom took great issue with Lowell on the need for powerful computers in space.

"Battle management and command and control," he said, "are very difficult. And to the extent that you need to have reasonably autonomous intelligent platforms [such as orbiting battle stations and satellites], that might drive computer requirements higher."

"Your people," said Lowell with a huff, "have not even *begun* to make that case. Their computer requirements for doing their tasks are really quite modest for boost-phase intercept."

"I agree," said Tom. "And I think they have even overestimated it for particular tasks."

Victorious, Lowell turned to me and said: "Here's the problem. The guy has fifteen hundred missiles, and they're burning for a hundred and fifty seconds or more. That's a ten-per-second total that you have to handle in boost phase. If he's finally got his warheads coming down on you—and his warheads and decoys and penetration aids are several hundred thousand objects, and you only have a few hundred seconds to cope with them—then you're faced with thousands of objects per second, each one of which is of very great importance. They're much smaller. They're much harder. They're coming much faster. And they don't have a bright flame broadcasting their location like a booster does. And so your problem becomes a lot more demanding, not just because of all these other nasty features. You have to get awfully close to your targets, and you have to kill them with very stringent means. And if any significant fraction of that stuff gets through, you die."

"It's not just computers," said Tom, coming back to the original point. "There are questions of high-precision manufacturing techniques—mass production techniques—that are very challenging to us and, I would imagine, even more challenging to the Russians. But if they choose to concentrate resources on that area, I would say they probably could make them. Whether they'd permanently lag several years behind is hard to say. It probably depends on their commitment. In the long run, I don't think we can count on any technological advantage."

I asked what was so threatening about the Soviets.

"There's one thing that keeps jumping out at you again and again," Lowell said. "The Soviets won't have to be pushed very hard to preempt." In other words, if they felt an enemy might be preparing to use nuclear arms, they would quickly be first to launch an attack.

"They're not postured to do anything else," Lowell continued. "And they don't have to be pushed very hard to do it. They are set up—and I can't go into the grubby details—but they will not preempt in a hair-trigger fashion. They will make up their minds on time scales of hours or a day and go ahead and do it. It will be done in a very methodical, cold-blooded, brutal, paranoid fashion. They'll just preempt. And they will preempt whenever they do the geopolitical calculus and decide it's better to go this way than that. They'll just go ahead and do it—kill a hundred or two hundred million people."

But that's not new, I said. According to such authorities as Joseph Douglass, Jr., and Amoretta M. Hoeber, preemption had long been talked about as a Soviet military strategy.

Wired for Preemption

"No," he said, "it hasn't been their strategy because they haven't had the means to implement it until about a half dozen years ago. It's only since they've developed heavy ICBMs, since they've developed a lot of missile-firing subs. These things keep jumping out at you. Someday—maybe out of the clear blue sky, because that's the way they're postured, that's the way they're wired—BAM! It will all be over. It's chilling. It's hard to get out of your mind. This is the only way their system works for strategic command, control and communications. You toy at it month after month,

year after year. What other interpretation could you give to the fact that they have this capability and no other capability? They send out their equivalent to our Emergency Action Messages. But it isn't: 'Quick, quick. Go, go.' It's: 'At such and such a time on such and such a date, you'll do so-and-so.' It's as methodical as a guillotine."

Our Mobile Deterrent

Lowell was right. Preemption was a terrifying possibility, but it was a threat only to America's land-based missiles. In addition, the United States had a huge mobile deterrent in the ocean. On Poseidon sea-based missiles there were more than 3,000 warheads, and on Trident missiles an additional 2,000 warheads, with thousands more on the way. And Tomahawk sea-launched cruise missiles were being deployed on submarines, cruisers and destroyers, their nuclear warheads planned to eventually number 1,000. Only a madman would want to shoot at America's land-based arsenal and then have to tangle with its nuclear deterrent at sea.

By contrast, the Russians had most of their warheads on land-based missiles, and therefore had more reason to fear threats of preemption. And such threats had been made. General Curtis LeMay, once head of the Strategic Air Command, had written that such battle plans were standard when he presided over the nation's land-based nuclear arsenal. "We spent a great deal of our energies learning what the opposition was doing day to day," he wrote. "Believing I could foresee an attack, I was prepared to beat him to the draw and attack all of his bomber and missile bases."

In breathless detail, Lowell described how the Soviets used their arsenal not just as the means of deterrence or preemption but as a big stick in the conduct of foreign policy. But he failed to mention that the United States did the same. The Soviets had backed down in the Berlin crisis and Cuban missile crisis partly because of the American nuclear threat. And during the Middle East crisis of 1973, the United States had used its very facile nuclear-alert system to encourage moderation on the part of the Soviets. In his memoir, *On Watch,* Admiral Elmo Zumwalt, Jr., recounted how the worldwide nuclear forces of the United States had been put on DefCon [Defense Condition] 3, the highest alert ever, in order to demonstrate how serious America considered the situation. Surely both superpowers excelled at the art of nuclear brinkmanship.

It was past 2:00 A.M. as Lowell and I drove down the interstate in our separate cars, he going back to the lab while I headed for his home at Windy Ridge, where I had been staying. The evening's discussion had convinced me that the battle plans for both nuclear war and defensive shields were much more complex than I had ever imagined. ■

THE BUTTON

Continued from page 81

importance of crippling the [Soviet] command and the control system . . . assumes extraordinary proportions.

"Limited Nuclear Options," Holloway continued—the kind of strikes associated with a strategy of controlled escalation—"are not feasible. Only if we are able to reestablish unequivocally United States strategic force superiority (in our minds and the enemy's) is there any reason to believe that LNOs can lead to successful negotiated settlement. It would be quite the reverse; and regaining strategic superiority in the proximate future is an extremely unlikely condition." He goes on to describe the kind of offensive against the Soviet leadership that he believes must be the centerpiece of U.S. war plans. "Degradation of the overall political and military control apparatus must be the primary targeting objective. Irrespective of whether we strike first or respond to a Soviet strike . . . it assumes the importance of absolute priority planning. Striking first would offer a tremendous advantage, and would emphasize degrading the highest political and military control to the greatest possible degree."

And, in fact, despite all the emphasis on controlled escalation, a senior officer told me that "there is no provision in the SIOP for controlled escalation. It is essentially a set of fixed plans." Of course, the President can try to negotiate with the Soviets in a crisis if he wants, but the military options were not designed with any step-by-step bargaining process in mind. The main option at the moment is a first strike whose goal is to kill Soviet leaders and thereby paralyze their command and control system.

"There's a real dilemma here that we haven't sorted out," General Scowcroft said, in that the use of "controlled nuclear options" to force concessions from the Soviets "presume[s] communication with the Soviet Union. And yet, from a military point of view, one of the most efficient kinds of attack is against leadership and command and control systems. . . . This is a dilemma that, I think, we still have not completely come to grips with."

Falling Off the Bridge

General Scowcroft did not say when, or how, U.S. strategists were going to resolve this question, although the lack of an answer has not stopped the United States from moving ahead with weaponry for making a first strike on the Soviet leadership. The question whether it is better to plan to kill Soviet leaders or to keep them around to negotiate with has simply been left open. The subject is treated in the way it is customary for Pentagon planners to handle other important problems that they are unable to resolve. The official attitude is that we will fall off that bridge when we come to it. ■

SKIN

Continued from page 79

So, what does all this brilliant research mean to the average burn patient, lying in bed, bathed in pain, trembling with cold and evaporating fluids at an ungodly rate?

Unless he has third-degree burns, which destroy the dermis entirely, nothing at all. Less serious burns, first- and second-degree, generally don't require grafting at all, and for such patients the body needs only support and protection until the natural process of healing can occur. And even if a patient does have third-degree burns, it's not clear that any of these new techniques are greatly superior to the conventional type of grafting—that is, unless the patient has such extensive burns (on over 50 percent of his body surface) that he can't provide his own graft material. For such patients, these techniques could be lifesaving. But each has some risks. Green's technique can cover large areas, but it involves substantial delay. Hefton's technique may set up the risk of graft rejection. Yannas's two-layer membrane, by introducing a large amount of foreign material, may set the stage for infection as well as rejection.

Realization of Dreams

To a doctor, conservatism comes naturally. New medical technologies are constantly being introduced, much ballyhooed and blazing with promise—and often disappear quickly in a cloud of unanticipated complications. Every new technology must be tested against the old reliable ones. And only by consistent superiority does the new technology find its place—most often it goes by the wayside or is indicated for only a small minority of patients.

One thing is clear: The whole field of skin replacement is trembling with breakthroughs. The basic work has already been done; dreams are tantalizingly close to realization. Surely it can't be more than a few years before a fully workable one-step process of skin replacement will sweep through burn care.

"Our success," says Dr. Green, "has come because the epidermis is so simple. It's really just one cell type. There are other cells present, but they're less important for structure or organization."

Now, the Next Question . . .

And the trick, really, has been in discovering how to allow that one cell type to assemble itself into skin—whether in the foreign environment of a laboratory flask or in the equally strange setting of an artificial membrane. That is, how to get human skin to grow in the lab. That question's been largely solved. And now a new one is emerging: What's the best way to get skin that's living comfortably in a laboratory to adapt to the unfamiliar environment of a human being? This question is just beginning to be addressed. ■

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ARMS BAZAAR

Continued from page 58

flight demonstration at the show every day at 3 P.M. It includes loops, slow and fast, vertical climbs and tight, steeply banked turns that subject the pilot to 8 g's or more.

The French, of course, counter with demonstrations of the Mirage 2000, a dazzler in its own right. Arms sales are important to France—the world's third leading weapons exporter (after the United States and the Soviet Union). The French, however, have an added advantage at Paris. Delegations from foreign governments are hosted by French guides. The French government pays their hotel bills, provides them with chauffeurs and packs their agendas with visits to French manufacturers. When the visitors tire of the Air Show, they are whisked off on escorted tours of Paris and the chateau country. "I'd love to sit down with the Egyptian chief of air defense," says Thomas Pavlock, Raytheon's manager for the Near East. "But I can't. The French have scooped him up."

Sophisticated Air Defense

Raytheon's presence, however, is certainly felt here. The company has brought its new Patriot air-defense system to Paris. Consisting of a missile launcher, a radar station and communications trailer, it is perhaps the most sophisticated ground-to-air system of its kind in the world. Patriot's phased-array radar bounces radio waves off an intruding aircraft to obtain heading, range, altitude and speed. After a missile is launched, data from the ground radar and a small radar in the missile itself are compared by computer to calculate an intercept point precisely. Communication takes place via a "data link" that is difficult to jam.

The first Patriot units have been delivered to the U.S. Army. Germany and the Netherlands have agreed to purchase the system. Negotiations are now under way with Belgium and Italy.

Buying and selling, however, is not the only business that goes on in Paris. A peculiar activity has come to characterize the Air Show: overt espionage.

Over wine, pâté, steak, assorted cheeses and pastries at Raytheon's chalet, Claudine Fraiture, an aeronautical engineer from Belgium, chats with Edmund Woollen, a company vice-president. Fraiture is the company's first female "consultant"—a euphemism for spy.

Fraiture travels the world attending trade shows like Paris to gather information for her clients. She traffics in gossip, picking up a tidbit here and passing on another there. Her contract with Raytheon calls for her to keep the company informed of what competitors are doing and also of contemplated actions by European nations that could affect Raytheon's interests. She also works for the Belgian government, arranging sales of weaponry between the United States and that country.

"You know, they call me a consultant," she says. "But I am really no more than a gunrunner."

At the General Dynamics chalet, she is embraced and kissed by an executive who directs the Stinger missile program for the company. The Stinger is a ground-to-air missile fired from a 35-pound shoulder launcher by a single infantryman. It homes in on the infrared radiation of a jet fighter's hot exhaust. In hushed tones, Fraiture asks if he has heard that Belgium has decided to purchase the French Mistral missile instead of the Stinger. "You just ruined my day," the executive sighs. "I can't believe he didn't know," she confides later.

Spying with Calipers

The Russians, like Fraiture, are also here for information. "They come to find out what's new," says Raytheon's Pavlock. He explains how at past air shows the Russians walked around with calipers and cameras, measuring the diameters of missiles and the thickness of wing roots. By knowing the diameter of a missile they can estimate how much propellant it contains and infer its range. From the thickness of a wing root, they can determine bending loads and estimate performance characteristics. "You can be sure they'll be out there measuring the X-29 with their calipers," explains Pavlock.

"Spies look for the same thing as marketing competitors," says Ed Woollen. "They're interested in what their competition is building and planning to deploy in three years. That gives them an opportunity to put out a counterproduct." The Russians and Japanese, who are the "boldest" when it comes to measuring and photographing at Paris, "are great at reverse engineering," says Woollen. "They see what you're doing and copy it. But they wait for you to make the mistakes first."

Delivering Umptifratzes

Is the Air Show worth the $4 million Raytheon expects to spend here? "We never expect to sell hardware just because it was first seen in Paris," says Woollen. "It's not like the spring fashion shows. It gets down to the marriage that has to be between suppliers, buyers and governments. Normally we speak to each other on the phone or in structured meetings. But the real business is always done through back channels, where you can try out crazy ideas or tell someone he's screwed up because he hasn't delivered the aluminum umptifratzes on time. Diplomats have their cocktail parties. We have Paris." ■

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Want a walking insecticide?

BY PIERCE G. FREDERICKS

Moloch was an ancient god to whom children were sacrificed, and he probably was *horridus*. The Australian thorny devil, *Moloch horridus*, is—despite its appearance—a threat only to ants. They are its food supply, and when the lizard gets on an ant trail, it can put them away at the rate of 20 to 30 a minute. One moloch was seen to eat 1,800 of the insects at a single sitting.

If some predator should try to make a meal of moloch, however, the lizard is in trouble. It is only about eight inches long and a slow-mover. Rather than make a fight of it, moloch turns to passive defense. Its coloration can change to blend with the background. If the deception doesn't work, moloch will put its head between its forelegs, thus presenting the predator with the lump on the back of its neck, and hope that the sharp, stiff spikes on its back and legs will deter snakes and larger lizards, which must swallow their prey whole.

Much about moloch brings to mind the North American horned lizards: They, too, are no beauties and have a pronounced ant tooth. Curiously, the two share no evolutionary history. The thorny devil has relatives in Europe but none in North America. Moloch is, in fact, so different from the rest of its lizard family, the Agamidae, that it is believed to have a long history of evolution in isolation. Creatures such as moloch and the horned lizard are known as ecological equivalents.

Living in the central Australian desert has its problems, of which obtaining water is not the least. Moloch has evolved a solution. When it does get to a puddle or water hole, every square inch of its skin begins to absorb water through tiny canals between its scales. The water doesn't go through the skin and into the body; if it could, a double game would come into play—the water would sweat out the same way it came in. Instead, the canals lead the water around to the edges of moloch's mouth, where the lizard can suck it in by moving its jaws.

An ant-and-water diet does not seem, on the whole, like a very attractive life, which may be the reason that *Moloch horridus* is the only species of its genus. ■

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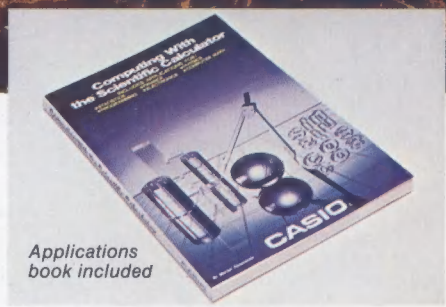

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